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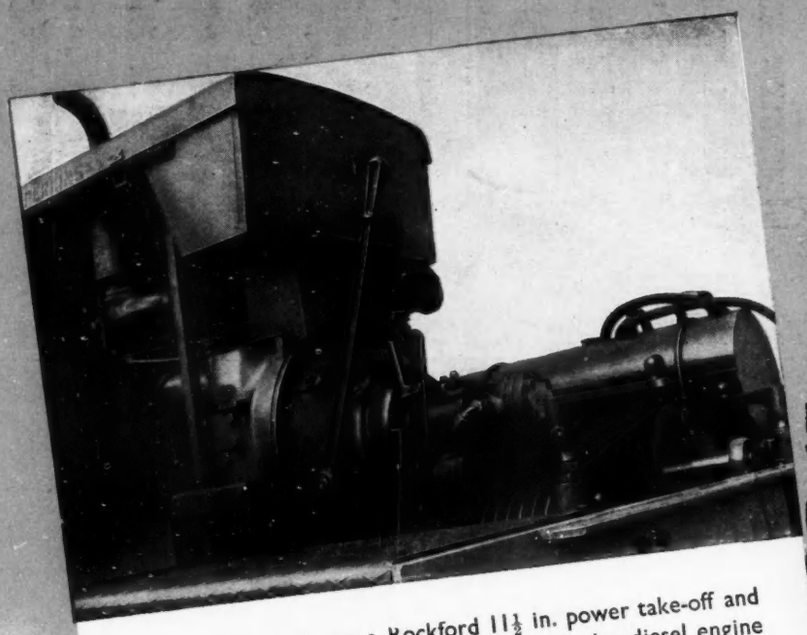
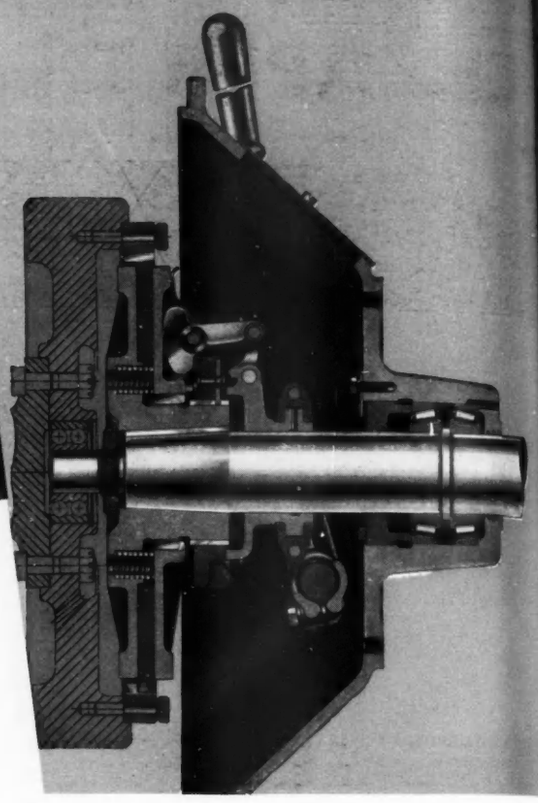
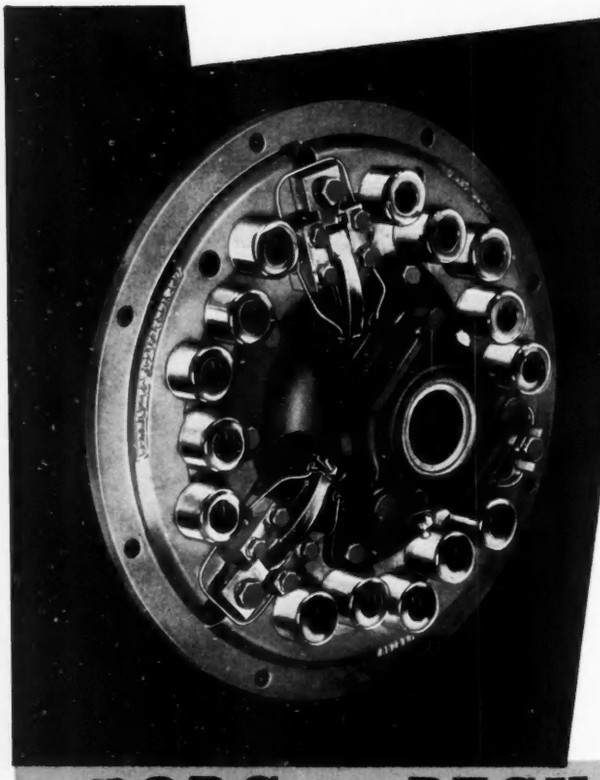
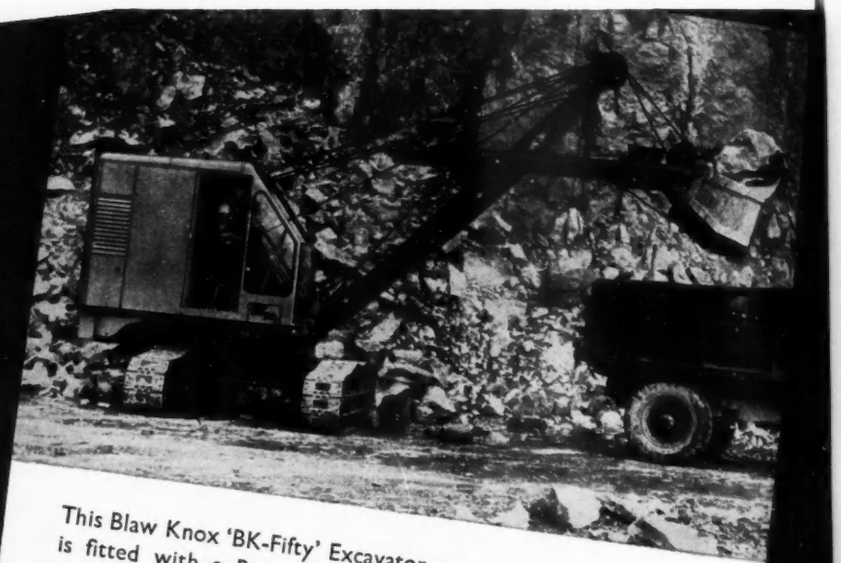


This illustration shows a Rockford 11½ in. power take-off and 'over-centre' clutch unit on a Perkins 4-cylinder diesel engine on the Blaw Knox PF-90 Bituminous Paver Finisher. This interesting machine can lay pavement in any width from 8 ft. to 13 ft.
At right, a typical Rockford power-take-off unit.



ROCKFORD CLUTCHES & POWER TAKE-OFFS





This Blaw Knox 'BK-Fifty' Excavator, seen at work in a quarry, is fitted with a Borg & Beck 14-inch clutch. Borg & Beck clutches are used on the majority of Britain's commercial vehicles. A recent addition is the Borg & Beck combined clutch and power take-off.

CATALOGUES OF ROCKFORD 'OVER-CENTRE' CLUTCHES, AND BORG & BECK CLUTCHES, WILL BE SENT ON REQUEST.

BORG & BECK FRICTION CLUTCHES

BORG & BECK COMPANY LTD., LEAMINGTON SPA, WARWICKSHIRE, ENGLAND

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ENGINEERING

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A Sense of Balance

"A BALANCED partnership between science and business" was the theme which Sir Alexander Fleck developed in his presidential address to the British Association in Glasgow on Wednesday. He could have claimed—though he didn't—that the famous chemical firm of which he is the head has achieved a fine balance of partnership between science and business. It would be fascinating to apply the test to many firms and organisations—large and small—but as aircraft and atomic energy are the two branches of engineering which figure prominently this week, let us apply it to them.

In no other British industry, probably, is science and engineering so well represented in management as in the aircraft industry. With few exceptions, the managing director is an engineer—often the chairman too—as well as a high proportion of board members. Taken as a whole, this management structure has worked well, as the healthy growth of British aircraft exports bears witness. The aircraft industry's export story also bears out Sir Alexander Fleck's point that "the balance that we seek must come in great measure from within the individual himself"—the aircraft companies that are most successful in marketing their products are those in which the engineering leaders have also shown themselves to be business men. But an aircraft company may be technically brilliant, with a fine record of achievement in prototype form, yet fail to obtain sufficient contracts if the board and senior executives are technically minded but blind to business.

The converse is equally true. A company that places its faith exclusively in business insight will soon find itself with nothing to sell. But neither of these extremes is common; the problem is rather to determine the point of balance at which the two forces in an enterprise are in proper equilibrium. In certain older industries business predominates, but in industries where there is a constant and pressing demand for technical innovation, the scientists and engineers may, by a sort of blackmail, outweigh the judgments of their commercially experienced colleagues.

A nuclear power plant, like an aircraft, involves enormous investment in research. Atomic energy is a particularly significant case, since it began life in the laboratory and has only recently become commercial. The design of a nuclear reactor cannot even begin until a lengthy series of studies have been completed. Long before a project is undertaken, a huge research team must be assembled; and its leaders, secure in their special knowledge, can command an allocation of funds not easily assessed by a business man unversed in the methods of science. How can the balance be redressed? Scientists and engineers may be enlisted on the commercial side of management, but the transfer should be made at a stage when they have learnt at least something of technical work. A company may be strengthened financially by joining with other companies to form a consortium. It is not only to undertake large multi-character projects that groups of this kind have been created, but also to support the large research teams necessary to these projects, projects which may require six or seven years to yield returns.

As the size of nuclear power stations increases, without any conspicuous rise in capital cost, the intervals at which companies can expect to secure orders grow longer, so that the problem of sustaining teams of scientists becomes ever more severe.

Another aspect of the same question is the need to establish large national research bodies to carry out fundamental research. No firm or group of firms could have brought nuclear power to the stage of fruition; the cost was far too great. Business, as a result, can no longer operate in the unfettered way to which it has been accustomed: the scientists, this time in the national establishments, have too much influence. If the government body chooses to develop one reactor system and to neglect another, companies that have taken up the rejected system will be deprived of basic information. This is unavoidable, since a choice must be made. But the balance between science and business is inevitably affected. As a measure of the extent of this influence, the technical papers to be presented at the Geneva conference by the United Kingdom Atomic Energy Authority vastly outweigh those submitted by private firms.

Engineers have a great opportunity to keep science and business in balance. Their education, training and experience should enable them to take the whole view of engineering—what Sir Willis Jackson calls "the economic application of scientific research." This function of the engineer was foreseen 130 years ago, as Sir Alexander Fleck recalled in a quotation from Auguste Comte: "The establishment of the class of engineers . . . is the more important because this class will, without doubt, constitute the direct and necessary instrument of coalition between men of science and industrialists, by which alone the new social order can commence."

Cover Picture. *The Vulcan bomber, now in service with the Royal Air Force, is capable of near-sonic speeds at altitudes of 50,000 ft and higher. The Vulcan is designed to carry a stand-off bomb.*

* * *

Plain Words

Science, aided and abetted by engineering, is taken to task for many faults not properly its own. To scientists are attributed all those potential horrors of our times that wake publicists and playwrights screaming in the night. I see that the doughty Sir Alan Herbert has lent his light but awesome lance to tilting at the half-seen shadows of scientific progress, and I fear he may have unseated a few unsuspecting riders.

He considers that science is so revered to-day that anything the scientists may choose to do is never questioned; and that their experiments, whether or not they harm the rest of us, are relentlessly pursued to their frightening conclusions. He proposes —and it's not a bad idea at that—an international council, appointed to vet scientific projects and prohibit those involving hazard or discomfort for the body of mankind.

In particular, he is afraid that someone may direct a nuclear missile at the moon, which will thereupon burst into flames, giving us a sun in the morning and a sun at night—a situation which he rightly considers would be very trying. His humour has a core of real dismay; but is he right to blame the blinkered selfish curiosity of scientists for our present lunatic conditions? After all, the first scientist to protest in any effective manner is likely to lose his job or go to prison.

It is not the scientist who gets his way; he is like the child who is bidden to perform before an audience of relatives or visitors. He isn't keen and they are bored to watch. The scientist may be lavished with equipment, but only if his purposes coincide with the aims of those who call the tune. It was not until rockets and satellites were seen to serve some national interest (for warfare or prestige) that the astronauts were given their heads—and the necessary money. Nowadays there is an ambiguity in the function of the scientist that has never existed before. Does he serve his curiosity? Or does he serve those who foot the bill? Astronauts are specially faced with this dilemma.

Surely if it were not for the childish rivalry between nations, there would be no talk of putting bombs on the moon, like flags on a mountain, to record a futile triumph. No real scientist would dream of smashing his specimen to find out how it worked.

There is nothing wrong with curiosity, nor with its fruits, as there is nothing evil in a tool. Space research, in any case, has an attraction that transcends the common appetites of everyday. And perhaps there is something in our racial consciousness that bids us seek an escape route from this planet. I often feel like getting off myself.

CAPRICORN

Weekly Survey

Canadian Hydro-Electric Capacity

An article, "The Future of the Hydraulic Turbine," in the current issue of the *Dominion Engineer* (vol. 25, No. 2), puts forward views on the hydro-electric development of Canada which are of interest to hydraulic turbine manufacturers both within and outside the Dominion. The author notes that installed hydro-electric capacity in Canada at the end of 1957 was 19·9 million h.p. and that the estimated commercial potential is 74 million h.p. This leaves approximately 54 million h.p. to be developed, and it is suggested that this development may take place at the rate of about 2 million h.p. per annum for the next 27 years. The figure of 2 million h.p. is taken as representing the maximum rate of Canadian water turbine production to date and it is pointed out that Canadian turbine exports have only slightly exceeded imports.

It is, however, considered that certain developments may expand the life of the water turbine business beyond this period. For example, diversion from an uneconomic to an economic watershed has increased the capacity of individual installations and further diversions may increase the ultimate potential. Considerations of load factor may also be important. If the total demand for electricity necessitates the erection of thermal plants, it may become desirable to use hydro-electric plants for peak loads and, if suitable storage sites exist, it is possible that a site rated as suitable for 1 million h.p. at 80 per cent load factor may be developed for 8 million h.p. at 10 per cent load factor, thus increasing the demand for water turbines. Pumped storage may also justify the development of capacity beyond that based on a dependable flow of water. The conclusion reached, therefore, is that 27 years can be regarded as a minimum and that some increase in the rate of development may in fact occur.

France's Pipeline to Prosperity

A number of British oil companies have joined French, German, American, Dutch and Belgian companies in an international project to pipe oil from Marseilles to Strasbourg. This is the Société du Pipe-Line Sud Europeén and the companies involved include B.P., Royal Dutch, Standard Oil, Caltex and the French giant C.P.F. (Compagnie Française des Pétroles). The scheme includes the building of two large refineries in the Strasbourg district which will supply an area including East France, the Saar, South-West Germany and parts of Switzerland. The pipeline, 24 in diameter, is expected to bring down prices in this area below those of river-borne oil coming in from North America and the Middle East. Other pipelines are already under construction from Cologne to Rotterdam and Wilhelmshaven, and the new line may be connected to these at Cologne so as to bring in oil through the North Sea cheaply.

The new developments are part of a plan which will put France in second place after the United Kingdom among West European oil-refiners; the French target for 1963 is an increase of 12 million tons over the present annual output of 33 million tons. At present 80 per cent of the crude oil used by France comes from the Middle East but developments in the Sahara will, it is hoped, considerably reduce this proportion. This may prove a slow business however, as less than 1½ million tons out of the 20 million consumed last year came from North Africa. Whether the Marseilles-Strasbourg pipeline is extended northwards to Cologne to join up with the Rotterdam and Wilhelmshaven pipelines or not, French and German firms hundreds of miles from the sea will now have the advantage of cheap oil supplies, with all that this will mean to their ability to compete with Britain and other countries in the West European market.

India's Ability to Import

In spite of measures taken by the Indian Government to conserve foreign exchange resources, some reinforcement of the country's foreign exchange reserve is now regarded as a matter of urgency if default on overseas payments is to be avoided. Methods of avoiding default and of preventing a recurrence of present difficulties are under consideration at a meeting in Washington between representatives of India, the United Kingdom, the United States, Germany and Japan, under the aegis of the World Bank.

At the end of the first week in August, India's free reserves to meet external liabilities, after allowing for the minimum statutory reserve against the note issue, amounted to about £80 million. Commitments to 30 June, 1959, after allowing for proceeds from exports and credits already granted, total about £200 million. The overall balance of payments deficit from April, 1958, to the end of the second five-year plan in April, 1961, is estimated at £460 million. Of the debts due in this period about 50 per cent is accounted for by the United Kingdom, 20 per cent by Germany, 10 per cent by Japan and the remaining 20 per cent by other countries, of which the most important is the United States. The Indian Finance Minister recently pointed out that weekly average drawings on India's sterling balance had been reduced to Rs.40·9 million in the first seven months of 1958, compared with Rs.72 million in the corresponding period of 1957. But, in spite of this, there was a net fall of Rs.740 million between April and July in the total sterling reserve.

In India the significance of this situation is seen primarily in relation to the future development of the second five-year plan. Other countries are concerned principally with the political repercussions in India which would be likely to follow a financial breakdown, and also with the effect on international trade resulting from a big curtailment of Indian imports. The British engineering industry, in particular, must view the outlook with concern, since although some 85 to 90 per cent of the commercial credits granted to India are covered by guarantees from the Export Credit Guarantee Department, any marked reduction in Indian imports must be reflected in a serious decline in British engineering exports.

Israel's Resources

The director general of Israel's Ministry of Development, Menahem Bader, discusses his country's natural resources in the August 1958 issue of the *Anglo-Israel Trade Journal*. Agricultural products are still the most important constituent of total exports, amounting in 1957 to 53·7 million dol out of total exports valued at 134·6 million dol; but industrial exports had reached 45·4 million dol and exports by the development corporations, covering potash, phosphates and general fertilisers, had reached 3·3 million dol.

The country's natural resources are situated in the Southern Negev—an area which constitutes about half the total territory but at the time of the establishment of the State of Israel was almost completely unpopulated and without water. Very little was then known regarding the resources of the area. Field survey was carried out by the Scientific Corps of the Israel Army and later by the Israel Mining Industries

Company and the Geological Survey Institute of the Ministry of Development.

The next stage was the building of the Beersheba-Sdom road across the Negev from west to east and of the north-south road to Eilat. Following this, the potash works at Sdom were recommissioned, the phosphate works were erected at Oron and the Fertiliser and Chemical Company's plant at Haifa expanded. Later developments included the erection of a bromine factory at Sdom and the development of a copper mine at Timna. The rate of development is shown by the fact that the output of potash increased from 50,000 tons in 1956-57 to 85,000 tons in 1957-58, and is expected to reach 100,000 tons in 1958-59. Corresponding figures for phosphate are 114,000 tons in 1956-57, 140,000 tons in 1957-58 and 250,000 tons in 1958-59.

Further development depends on the solution of two fundamental problems: the supply of industrial water and the development of cheap transport. It is hoped to overcome the former by exploiting local sources of low salinity, and by desalting sea water. An experimental sea-water plant has been erected by the Ministry of Development and will start operation soon.

Holland May Turn Off Coal Gas

With increasing quantities of gas available from local natural gas fields, coke ovens and oil refineries, the Netherlands Minister of Economic Affairs expects that the production of coal gas may cease in Holland in a few years time. When this happens, the existing gasworks will be needed only for peak load production of carburetted water gas or for the transformation of high-calorific into low-calorific gas. The changeover to new sources of supply is accompanied by the development of an integrated pipeline system. This will cover the whole country and ensure a high degree of flexibility in supply.

Natural gas production by N.A.M., Royal Dutch, Shell and Jersey Standard started in 1952. It has reached a rate of 550,000 cu. m a day. Nine-tenths of this output is from the fields in the north-east of the country. The remainder comes from a field to the west of The Hague. Eventually it is expected that production of natural gas will exceed 350 million cu. m a year. Refinery gas from the Pernes, near Rotterdam, plant of B.P.M. Royal Dutch Shell and of Caltex, has been used as town gas for the past five years. The amount supplied has been around 170 million cu. m a year. Coke oven gas supplies have now risen to about 660 million cu. m a year. Annual output of coal and water gas from gasworks has fallen from 880 million cu. m in 1950 to 612 million cu. m in 1957. When the present pipeline programme is completed it is estimated that there will be an annual coal saving of 960,000 tons, which is equal to about 8 per cent of last year's coal production of 11,700,000 tons. For a country as short of coal and as heavily industrialised as Holland, this new development is going to be an increasingly important factor.

Czech Machine Tool Exports

One of the probable beneficiaries of the easing of east-west trade restrictions will be the machine tool industry, which raises the question as to what competition the industry is likely to encounter from beyond the Iron Curtain. The Czech machine tool industry, which is in the midst of a five-year plan, is working up to a position where it will be able to supply some 13 per cent of the world's machine tool needs. It is already the fifth largest exporter in the world, following the United States, West Germany, Britain and Switzerland. The Czech T.O.S. trade mark is known in some 90 foreign countries. This expansion is partly the result of Czechoslovakia having the well-established pre-war industry to build on. The old trade marks of Skoda, Zbojovka Brno, Volmann, Mas, Kamenicek, Podhajsky and others were well known in the 1930's.

Again, the policy of building up capital equipment and heavy industry east of the Iron Curtain has resulted in a large expansion of the machine-tool industry and the creation of a potential export surplus. The opening up of new markets in the under-developed countries of Asia, Latin America and the Middle East has provided new outlets for the Czech factories. In terms of quantity Czech productivity is the highest in the world, and in terms of value is as high as that of the United States.

Three-quarters of the machine tools produced in Czechoslovakia are now exported. About 60 per cent of these appliances went to other Communist countries in 1956. Elsewhere, Latin America was the biggest customer. Ibramag, the big Sao Paulo sewing machine company, has equipped its plant completely with Czech machines. Codbrasma, the largest railway carriage factory in South America, bought a big Czech boring and turning machine in 1956. Argentina, Colombia, Mexico and Chile have all increased their trade with Czechoslovakia in the past three years. Exports to Far Eastern markets are claimed to be 50 per cent higher in 1957 than in 1956. All told, the indications seem to be that the Czech machine tool industry is in a strong competitive position and that British makers will have to work hard to sell their products behind the Iron Curtain.

Terms of Trade

If the twenty years since 1938 are divided at the year 1950 we have two periods in which the country's Gross National Product rose by about £2,000 million measured in 1948 prices. But whereas all the additional resources were available at home in the second period practically all that produced in the pre-1950's was taken in balancing our overseas payments. This big difference is due in large measure to the swing of the terms of trade in our favour. What does this mean? Broadly the world's overseas trade is between manufacturing countries and raw material and food producing countries. If the terms of trade move in our favour it means that the prices of our imports and raw materials have fallen in relation to what we get paid for our exports of industrial products. The problems raised by movements of the terms of trade are discussed in an article by Mr. A. C. L. Day in the July issue of *Lloyds Bank Review*. One difficulty is that very little accurate knowledge is available about how the terms of trade have varied in the past. About the most that can be said is that over the last 70 years the primary producers have at best held their own and that they may have lost relatively to manufacturers. In the immediate past the collapse in commodity prices after the Korea boom has affected different regions in different ways. The Middle East oil producers have not suffered at all.

Compared with the first quarter of 1957, the price of sugar, crude fertiliser and non-ferrous metals fell by 20 to 30 per cent this year. Dairy produce, cereals, oil seeds, rubber and wool fell by from 10 to 20 per cent, and meat, coffee, cotton, other fibres and animal fats by 5 to 10 per cent. Some commodities, notably tobacco hides and leather, rose in price. But as Mr. Day points out, "the world is dynamic." Things don't stand still to let the statisticians get the figures written down in their notebooks. So far as the United Kingdom is concerned, the improvement of the last year or so is an unquestioned benefit, says Mr. Day. We now have to send out fewer goods to get the same level of imports, and we should see some easing in the general position of our balance of payments. This trend is likely to continue until activity starts to pick up again in the United States. As a guide to anyone making guesses about the long-term position, the writer makes some comparisons with some key dates in the past. In the first quarter of 1958 the United Kingdom terms of trade were 6 per cent less favourable than in 1938, but 24 per cent more favourable than in 1951 at the height of the Korean boom, about 11 per cent more favourable than in 1928 and some 26 per cent more favourable than in 1913. All this suggests "that the present position may be abnormally favourable."

Letters to the Editor

WORLD STANDARDS

SIR, A Weekly Survey note on world standards, published on p. 707 of your issue of 6 June, has reduced at least one design engineer from despair to apathy. Agreed in advance that it is grossly unfair to take a phrase out of its context, the whole thing is beautifully summed up in four words: "the growth is logarithmic."

It could be that the writer's experience is unique, for he has never yet met a fellow engineer who did not agree that standards are a futile waste of time, and yet has neither seen nor heard of any attempt to rectify the situation. In fact, the whole subject seems to be a sacred cow, whose existence it is sacrilege to question.

Nevertheless, the purpose of this letter is to state the reactionary opinion that, if a man knows the dimensions, angles, etc., of a thing, he should be happy, whereas if the same man is confronted by a drawing showing a collection of meaningless symbols (which, in this day and age, tend to take up as much space as the dimensions), he is obviously unhappy until he has spent either a fortune in acquiring a comprehensive series of reference books, or a day trying to locate the drawing office copy, which is invariably locked in the drawer of someone who is on holiday. The draughtsman has, of course, already gone through this procedure in reverse.

The no doubt well-intentioned people of the International Standards Organisation can be likened to oarsmen, who, while facing in one direction, attempt to travel in the other, with the exception that the skilled oarsman occasionally looks over his shoulder to try to see where he is going.

Yours faithfully,

J. C. TYSOE.

6 Stalmine Avenue,
Cheadle, Cheshire.
22 August, 1958.

RAILWAY ACCIDENTS

SIR, The letter from Mr. K. F. H. Murrell, published on p. 195 of your issue of 15 August, while apposite in some respects, contains an argument so erroneous and a view of "responsibility" so irresponsible that it should not be allowed to pass unchallenged.

In this by no means perfect world, as it actually exists, there are in use machines of all kinds in every state from the newest to those about to be withdrawn. In design, these machines will be in every stage from the latest development to the obsolete and, in condition, from those newly built or overhauled to those about to be withdrawn from service, either temporarily for repair, modification or rebuilding, or permanently for scrapping. This being the case, it is surely the duty and the responsibility of every operator of a machine to operate that machine correctly, within its limitations, at whatever stage in its career it may be, regardless of what other machines may be in existence in better (or worse) condition or of better (or worse) design.

To suggest that the operator of a machine is not to blame for failing to operate it correctly, whether the result is bad work or a calamity, because some other machine exists that would have been easier to operate, is sheer irresponsibility. The job which the operator has undertaken was the working of that machine and his duty was to perform whatever task that entailed.

Continued on next page

It is quite correct to say that management and designers should be aware, and take cognisance, of what is known about human beings to make the lot of those human beings less onerous in operating the machines that they use, but to state categorically that the blame rests on them for an accident because the machine involved was not in every respect up to the latest standard is utter nonsense.

In the case being considered, there is not the slightest suggestion by the Inspecting Officer, who is far better qualified to judge than Mr. Murrell, that the locomotive concerned was either unsuitable or unfit for the working of that train. The driving of such a locomotive was the job that the driver was qualified and was believed (and believed himself) to be fit to do in the circumstances prevailing. To say that the Inspecting Officer's reference to the fact that, on another kind of locomotive or train, it would have been possible to see the colour of the signals more easily (i.e., without crossing the cab to the other side) contradicts his finding of responsibility, is completely untrue. It does nothing of the kind.

If the researches of Mr. Murrell can lead to some practical means of assessing whether men are or are not still fit to carry out exacting duties, or can help in any way to make such duties less exacting, they will be helpful and welcome, but they are hardly likely to find acceptance if Mr. Murrell puts forward his findings on a subject in which he is presumably qualified with such stupid and arrogant dogmatism as he has written to you on a subject about which he is clearly quite unqualified.

A letter such as he has written is not in the least likely to help in attaining the ends that he has in view, which, strange as he may find it, are neither unknown to, nor neglected by, most managements and most designers, though inevitably some are better informed or keener than others. From all available information the betterment of the lot of the staff concerned in train operation is one of the objects, and not the least, for which the British Transport Commission is spending a vast sum of money in its " Modernisation " of motive power and signalling.

Mr. Murrell's categorical condemnation of the railway management and their designers for the occurrence of a lamentable catastrophe is unwarranted by the evidence, which has been thoroughly examined by a far more competent authority on the subject.

Yours faithfully,
D. R. CARLING.

The Mill House,
Braunston,
Near Rugby.
21 August, 1958.

ARCHITECTURAL FOUNDATIONS

The United States National Science Foundation recently granted funds to the American Institute of Architects for setting up a conference in Washington this autumn to identify the neglected areas in basic architectural research. A major aim of the conference has been described as " to determine the relationships of the physical, biological and social sciences in the problems of optimum-created environment for human activities." The steering committee for the conference comprises a sociologist, a psychologist, a public health expert, a structural engineer, and two architects.

As basic research is a long-term activity, an initial survey is being made of college architectural departments to determine which of their projects may be discussed at the conference. The current programmes are generally broad, but suggestions for further work have been made, including study of the problems of colour, sociology, and economics. At present it is estimated that less than 0·5 per cent of the total income of the United States building industry is spent on scientific research and that most of this is spent on manufactured products and materials.

COAL AND STEEL RESEARCH

One of the advantages of setting up a common organisation is that it enables activities to be undertaken on a scale that would be beyond the means of the individual members. This fact is borne out by the research programme recently announced by the European Coal and Steel Community. The Community's consultative committee, which consists of representatives of both managements and trade unions of the privately and publicly-owned coal and steel companies, as well as of consumers, has given its approval to six important projects. The first is for a joint project by the Charbonnages de France (the French equivalent of the N.B.C.) and Steinkohlenbergbauverein, the German free-enterprise research institute, to construct a fully mechanised universal tunnelling machine capable of cutting underground roadways through all types of coal-bearing formations without drilling or explosives. The machine, which will load mechanically and continuously the material it cuts down, will cost one million dol, of which the High Authority will contribute 850,000 dol.

The second project is the provision of 10 million dol for a 15-year programme of prospecting for iron ore and manganese by the Bureau des Mines de la France d'Outremer in French West Africa. The High Authority's contribution will be 5 million dol. Project three is for research on the phenomenon of instantaneous escapes of fire-damp in mines. It will be carried out by the Fedechar, the Belgian Coal Federation, and the Charbonnages de France. The High Authority, in this instance, will find the whole of the 545,900 dol required. The fourth project is for research on ground pressure in mines, which will cost 1·7 million dol and, again, be financed entirely by the High Authority. It is being carried out jointly by Fedechar, Steinkohlenbergbauverein, Charbonnages de France and the Dutch mines. Various German organisations are combining to carry out the fifth project, which deals with the suppression of brown smoke from steel converters. The High Authority will contribute 475,000 dol of the 830,000 dol which this project will cost.

Finally, the programme includes three related projects for the direct reduction of iron ore. They will be carried out by the Italian State-controlled Finsider on a shaft furnace, by the German Verein Deutscher Eisenhüttenleute on a rotary furnace, and by the Centre International de Recherches Metallurgiques, at Liége, in Belgium. These research activities will cost 1·25 million dol, of which the High Authority contribution will be one million dol.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
" Electric Furnaces," by R. Whittaker. West London Branch. Windsor Castle Hotel, 134 King Street, Hammersmith, W.6. Tues., 2 Sept., 7.30 p.m.
" Manufacture and Uses of Mineral Insulated Cables," by H. W. M. Barker. North London Branch. Town Hall, Wood Green, N.22. Wed., 3 Sept., 7.45 p.m.
BRISTOL
Chairman's address on " Joint Boiler House District Heating," by F. C. Cummins. Bristol and West of England Branch. Grand Hotel, Broad Street, Bristol. Fri., 5 Sept., 8 p.m.
PRESTON
" The Electrical Contractor in Industry," by S. Carwin. Preston Branch. R.A.F.A. Club, East View, Preston. Wed., 3 Sept., 7.30 p.m.

British Institute of Management

LONDON
Elbourne Memorial Lecture on " The Great To-Morrow," by the Earl of Verulam. Royal Commonwealth Society, Northumberland Avenue, W.C.2. Fri., 3 Oct., 8 p.m.

Engineers' Guild

LONDON
Annual General Meeting. Discussion on " The Changing Pattern of Leadership," opened by Mr. A. R. Cooper. Metropolitan Branch. Caxton Hall, off Victoria Street, S.W.1. Tues., 23 Sept., 6 p.m.*

Incorporated Plant Engineers

LONDON
" Human Relations " by R. R. Hopkins. London Branch. Royal Society of Arts, John Adam Street, Adelphi, W.C.2. Tues., 2 Sept., 7 p.m.*
BRISTOL
Discussion on " Smoke Abatement and the Clean Air Act." Western Branch. Grand Hotel, Broad Street, Bristol. Wed., 10 Sept., 7.15 p.m.
DUNDEE
Films and Discussion on " The Manufacture of Town Gas." Dundee Branch. Taypark Hotel, West Ferry, Dundee. Wed., 10 Sept., 7.30 p.m.
EDINBURGH
Various short talks by branch members. Edinburgh Branch. 25 Charlotte Square, Edinburgh. Tues., 9 Sept., 7 p.m.
LEICESTER
" Aspects of Planning and Designing in Industrial and Commercial Buildings," by Hugh S. Smith. Leicester Branch. Bell Hotel, Leicester. Wed., 3 Sept., 7 p.m.
MANCHESTER
Chairman's social meeting. Manchester Branch. Engineers' Club, Albert Square, Manchester. Tues., 9 Sept., 7.15 p.m.

Institute of Petroleum

LONDON
" Harmful Effects of Electrostatic Charges on Machinery and Lubricating Oils," by Dr. T. Salomon. Wed., 17 Sept., 5.30 p.m.*

Institution of Engineering Designers

WELWYN GARDEN CITY
" Automatic Control of Maximum Demand," by B. A. Vuille. Hertfordshire Branch. Friends Meeting House, Handside Lane, Welwyn Garden City. Wed., 3 Sept., 7.30 p.m.

Institution of Production Engineers

BIRMINGHAM
Various short technical films. Birmingham Section. College of Technology, Gosta Green, Birmingham. Wed., 17 Sept., 7.30 p.m.
DUNDEE
" Problems Associated with Spark Erosion," by W. Ullmann. Dundee Section. Royal Hotel, Union Street, Dundee. Wed. 3 Sept., 7.30 p.m.
NORWICH
Discussion on " Material Control Progress and Machine Loading." Norwich Section. The Assembly House, Norwich. Wed., 10 Sept., 7.30 p.m.
SHREWSBURY
Film on " Copy Turning." Shrewsbury Section. Technical College, Shrewsbury. Wed., 24 Sept., 7.30 p.m.

Modular Society

LONDON
Discussion on " Modular Assembly After Its Erection," and a display of drawings. Building Centre, Store Street, W.C.1. Wed., 24 Sept., 6 p.m.

Society of Chemical Industry

NEWPORT
" Some Factors Affecting the Performance of Condenser and Heat Exchanger Tubes," by Dr. P. T. Gilbert. Corrosion Group. Joint meeting with the South Wales Section of the Society and the Cardiff Section of the Royal Institute of Chemistry. King's Head Hotel, Newport, Monmouth. Tues., 16 Sept., 7 p.m.

Society of Instrument Technology

BIRMINGHAM
" Fuel Efficiency and Smoke Abatement," by C. A. J. Plummer Midland Section. Regent House, St. Phillip's Place, Colmore Row, Birmingham 3. Fri., 12 Sept., 7 p.m.
GLASGOW
" Circuitry of a Typical Digital Computer," by F. Bailie. Scottish Section. Scottish Building Centre, 425 Sauchiehall Street, Glasgow. Fri., 19 Sept., 7.15 p.m.
NOTTINGHAM
" Instrumentation in the Hosiery Industry," by D. L. Munden. East Midland Section. Nottingham and District Technical College, Shakespeare Street, Nottingham. Thurs., 18 Sept., 7 p.m.*

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than three weeks before the date of the meeting.

* An asterisk is placed where it is understood that refreshments are available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury Square London, W.C.1. (LANgham 5927.)
British Institute of Management, Management House, 80 Fetter Lane, London, E.C.4. (HOLborn 3456.)
Engineers' Guild, 78 Buckingham Gate, London, S.W.1. (ABBey 7315.)
Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111.)
Institute of Petroleum, 61 New Cavendish Street, London, W.1. (LANgham 3583.)
Institution of Engineering Designers, 38 Portland Place, London, W.1. (LANgham 8847.)
Institution of Production Engineers, 10 Chesterfield Street, London, W.1. (GROsvenor 5254.)
Modular Society, 22 Buckingham Street, London, W.C.2. (TRAfalgar 4567.)
Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. (BELgrave 3681.)
Society of Instrument Technology, 20 Queen Anne Street, London, W.1. (LANgham 4251.)

Companies in the News

Australian Contracts

Electrical development in Australia has resulted in two large orders to Australian subsidiaries of British engineering companies. Babcock and Wilcox of Australia received a boiler contract valued at over £8 million from the State Electricity Commission of Victoria, Australia, and Australian Electrical Industries Pty. a contract valued at £4·5 million from the same source. In both instances, the plant and equipment ordered is for the Yallourn Power Station in the Latrobe Valley.

In the case of the boiler contract, work valued at over £1 million will be carried out by the parent company at Renfrew. The contract includes two boilers suitable for operating continuously with brown coal. The A.E.I. contract covers turbo-generators and electrical equipment, and in this case plant to the value of nearly £2 million will be supplied from the United Kingdom by the Metropolitan-Vickers Electrical Company.

The rate of industrial development in Victoria has been very rapid in recent years and the Latrobe Valley has been called the Ruhr of the southern hemisphere. Since 1918, electricity development has been in the hands of the State Electricity Commission (formerly known as the Electricity Commissioners), which is also the largest individual fuel producer in Australia. The output of brown coal from opencast pits currently exceeds 10 million tons, and is planned to exceed 20 million tons, per annum within the next 10 years. Installed electricity capacity, excluding the new Yallourn Power Station in connection with which the above contracts were placed, totals 1·2 million kW; and within the next four years extensions to capacity totalling 240,000 kW will bring the capacity of the Yallourn Station alone to 600,000 kW. The Yallourn enterprise also comprises a brown-coal briquetting plant, which is the only one of its kind outside Europe.

It is particularly satisfactory that Australian subsidiaries of British companies should secure these contracts in view of the fact that two important contracts in connection with the Snowy Mountains hydro-electric scheme were recently awarded to United States companies. These were, however, mainly for construction work and it may be hoped that British companies and their subsidiaries will continue to supply a high proportion of Australia's requirements of electrical machinery and boiler-house plant.

Years of Separation

The inventive genius of an engineer, combined with the organising ability and foresight of a businessman have produced, in the case of the Alfa-Laval/De Laval group of companies, 75 years of uninterrupted growth spreading over 20 countries. The parent company, AB Separator, was formed in 1883 to exploit Gustav de Laval's invention of the continuous cream separator. This rested, as many others of the company's products, on the rational exploitation of centrifugal force. De Laval had much technical imagination, but also the ability to concentrate on the development and application of a basic principle.

The Alfa-Laval/De Laval group now employ 17,000 persons and have an annual turnover of some 750 million Swedish Crowns (nearly £52 million) on a market covering most of the countries of the world. The manufacture of cream separators led to that of other farm machinery, including many types of machine milling equipment, and of dairy machinery. The hermetic separator laid the foundation for the complete transformation of dairying, enabling the milk to be treated in a closed system. To this were added meters for determining the fat content of the milk, a homogenising centrifuge for the breaking down of the fat globules in milk supplied for direct consumption in order to prevent the formation of cream plugs in milk bottles, a range of plate heat exchangers for heat treatment, pasteurisation and cooling of milk and cream, pumps, churns, cheesemaking machines, and stainless steel tanks of up to 4,450 gallons capacity.

The growth of competition in most countries has not prevented the group's expansion but stimulated it. The development of separators and heat exchangers for industrial purposes, particularly in food and chemical production, and the manufacture of other products to provide a diversified output—car pressings, stainless steel kitchen furniture, washing machines, refrigeration machinery, incubators, are but a few of them—contributed to a rate of growth and stability which has been remarkable by any standards.

Cutting Their Coat

The continued decline in the activities of textile industries throughout the western hemisphere is having a severe impact on the textile machinery industry. The two major suppliers of card clothing—Card Clothing and Belting Company, and the English Card Clothing Company—have both experienced a decline in demand and an increasing tendency for their sales to be limited by import restrictions. In consequence, both are busy increasing their manufacturing facilities in overseas markets and diversifying their United Kingdom production to reduce their dependence on the home textile industry.

Both companies are investing in an Indian factory where machinery is currently being installed. In a short time they will be recruiting the necessary Indian personnel for training by their European technicians now in India. The chairman of English Card Clothing, Sir Alfred L. Mowat, told shareholders at the company's annual general meeting that plant and machinery at their Huddersfield factory were being modernised, particularly the wire-drawing department, and that the company would be consequently "well placed to meet the future."

Mr. A. F. Firth, chairman of Card Clothing and Belting, reported a reduced profit—£271,000 compared with £307,000 for the previous year—and indicated that exports of card clothing had continued to decline. The company are diversifying as rapidly as possible and during the year under review the greater part of their profits were obtained outside the textile industry. This would seem to be an inescapable trend, which can only be met by developing overseas manufacturing facilities and diversifying at home. Inevitably, the home output of traditional textile machines must decline and the industry's skills and experience in this field transferred to those countries which have emerged as leading textile producers.

Silver Lining

Orders worth some £10 million have been placed by London Transport for 532 high capacity carriages to replace almost completely the rolling stock now in use on the Piccadilly line. Much of this stock has been in service for 25 years or more and is obsolete. This order is the largest single step in London Transport's modernisation programme for the Underground, and involves rolling stock totalling 805 cars, either ordered or to be ordered, at a cost of more than £16 million.

The Piccadilly Line order will provide 76 seven-car trains to be added—between the autumn of 1959 and mid-1962—to the 15 modern trains now in service and the three prototype "silver" trains which have been running for some months. The design follows closely that of the prototypes. The major changes from 1938 stock are the use of rubber for the bogie bolster and axle-box suspension; the use of fluorescent lighting; and the panelling of the cars in unpainted aluminium sheeting. The placing of the control equipment underneath the floor gives about 15 per cent increased passenger capacity compared with the carriages now being replaced.

Thirteen firms participate in the order. Metropolitan-Cammell Carriage and Wagon will do all the carriage bodies and bogies—deliveries of which are due to begin in September next year at an average rate of four a week. General Electric Company will build 1,200 traction motors (costing £1¼ million); British Thomson-Houston have the order for traction control and auxiliary equipment; Westinghouse Brake and Signal for the brakes; Metropolitan-Vickers Electrical for motor generators; and G. D. Peters for door equipment. This will incorporate trackless doors, mercury door interlocks, and door-fault indicator lights. Other suppliers are A.E.C. (automatic coupling equipment), Peto and Radford (batteries), Clifford and Snell ('phone equipment), Patent Lighting (lighting and auxiliary equipment), Metalastick (rubber suspension), and Hoffmann (roller bearings and axle boxes and suspensions). Another order, for the Central Line, will be placed shortly.

From Bicycles to Bearings

The first bicycle with pedals was, it seems, a German invention and, as might be expected, the prime mover in the development of the ball bearing. Phillipp Moritz Fischer, 1812 to 1890, was the man who first constructed a pedal cycle. His son, Freidrich Fischer, took the first step in establishing the German bearing industry when, in 1833, he completed the development of the "ball mill." This machine, working on the centreless principle, made possible the grinding of steel balls in large quantities to a high degree of accuracy in both size and roundness. He founded a company, the Original Automatic Cast Steel Ball Factory, which developed rapidly during the first half of the century. Kugelfischer Georg Schafer Company, as they are now known, employ 10,000 people in the manufacture of ball and roller bearings and steel rollers. They have factories at Eltmann and Ebern, both in Lower Franconia, and are also manufacturing in Canada, at Stratford, Ontario.

Their British subsidiary, K.G.S. Bearing Company, recently exhibited Phillipp Fischer's bicycle at the B.E.A. Engineering Department Workshops, London Airport, against the background of a modern aircraft. The British firm operate as representatives of the German concern from Tettenhall, Wolverhampton, and distribute in the U.K. imported bearings and components, including deep self-aligning ball, thrust, taper and self-aligning, spherical roller types. The company are on both A.I.D. and M.O.S. lists, but this method of attracting attention to the company's products, by emphasising its long roots in German engineering, is original.

In the note "Reduced Expansion in Forgings" (Companies in the News, 25 July), we stated that Daniel Doncaster were nearing the end of their modernisation programme and were experiencing difficulties at their Sheffield works. They point out that next year's capital expenditure in the forge and other departments at Sheffield will be on an increased scale and that it is at Monk Bridge not Sheffield that capacity (which had been built up to meet Ministry of Supply needs) has exceeded requirements.

Atomic Review

World Programme

As a background to the Second International Conference on the Peaceful Uses of Atomic Energy, we summarise below the major national and international atomic energy programmes. Certain notes have been prepared by representatives of the countries concerned.

United Kingdom

Resources

Raw Materials.—currently more uranium is available than needed, the main sources being Australia, South Africa and Canada. There is no shortage of graphite; beryllium is imported from France, and heavy water from America, both these latter in research amounts.

Processing.—Natural uranium fuel elements of all types are made at Springfields, where a new plant is available, large enough to supply future needs. Capenhurst is expanded and supplies enriched fuel, for processing at Dounreay into enriched fuel elements for the fast breeder and for DIDO-type and MERLIN reactors at home and abroad. Plutonium separation at Windscale continues, expansion of plant being partly complete, and fuel from Canada and France is separated also. Large amounts of caesium are recovered.

Reactors

Existing Reactors.—Windscale No. 1, ZEUS and ZETR have finished their useful life. Over 30 reactors are in use or being completed, 16 being large power producers. Research reactors are used for isotope production, reactor and shielding study, materials testing, physics research and propulsion investigation. Apart from reactors built, possible systems are studied in detail.

Three Calder power reactors are now on load, the fourth nearly ready. Three at Annan will start in 1959, the fourth soon after. Eight large commercial power reactors (two per station) are under construction and will be on load in 1960/61, giving 1,400 MW electrical installed capacity. Further sites for 500 MW stations are announced. A 200 MW station is being built near Rome; an order for a 150 MW near Tokyo is expected soon. The British Nuclear Power Programme remains easily the largest in the world—at 5,000 to 6,000 MW (electrical) installed by 1966.

Power Reactor Development.—The Dounreay fast breeder reactor will go critical in the next few months. An advanced gas cooled reactor (AGR) is to be built, using beryllium canning and slightly enriched uranium, to work at higher temperatures and pressure, give higher burn-up and greater efficiency then the Calder system and go critical in 1961. A high-temperature gas cooled reactor (HTGC) is being built at Winfrith Heath, to use ceramic fuel elements, give high burn-up and temperatures, and conversion of thorium to fissile fuel.

Marine Propulsion.—The reactor NEPTUNE is employed for research into submarine-propulsion reactors. Systems for merchant ship use being studied include AGR., organic liquid moderated and gas-cooled heavy-water moderated reactors.

Research

Controlled Thermonuclear Reactions.—Work proceeds at Harwell, mainly with ZETA, temperatures over a million degrees being reached and stabilised for a few thousandths of a second. ZETA is being improved to reach higher temperatures, up to 30 million degrees or higher in a year or so. A smaller device, SCEPTRE, is working on the same principle at the A.E.I. Research Laboratory. Work on very rapid condenser discharge deuterium heating in straight tubes continues at Aldermaston, with temperatures exceeding a million degrees and reached very much more quickly than in the toruses mentioned above. All these devices emit neutrons. A larger version of ZETA is being designed and it is hoped the torus and straight-tube techniques may be combined, usefully, later in one assembly.

Fission Research.—Research shows that high-energy neutrons give more symmetrical fission of uranium 238 as well as higher neutron yields, up to 5 per reaction. Carbon bombardment of uranium gives even more symmetrical results, and up to 11 nucleons. Neutron interactions with higher plutonium isotopes (separated by HERMES) are being studied.

Fundamental Research.—A 7 GeV proton synchrotron is being built at Harwell for the National Institute for Nuclear Research, and a 50 MeV proton linear accelerator will be ready in 1959. The equipment will be available for university research workers. Several Van de Graaff accelerators are available for research together with high-energy accelerators at the universities. Britain participates extensively in the research projects undertaken by the European Organisation for Nuclear Research (CERN).

Isotopes and Schools

Isotopes.—Production continues to increase, the bulk being exported. At least five kilocurie caesium sources have been made. The Wantage Radiation Laboratory has growing facilities for intense radiation sources of cobalt and spent fuel and from accelerators. Graft polymers and food preservation are studied, and in addition insect destruction and plant breeding, thickness gauges and radioactive krypton light sources. Labelled compounds are widely available. The Isotope School holds larger and more varied courses than before and has trained staff for the Baghdad Nuclear Centre.

Schools.—Besides the Isotope School, the Reactor School at Harwell continues to train students both from the United Kingdom and abroad. A Reactor Operations School at Calder Hall gives courses for British and foreign students. Courses on reactor technology are now available at several of the universities.

Manufacture and Agreements

International Agreements.—Agreements for exchange of information and co-operation in research and power-reactor technology with many foreign countries continues, and with organisations such as OEEC, IAEA, and Euratom.

Consortia.—Five large consortia, groups of industrial firms, can build large nuclear power stations at home or abroad. Other firms can offer smaller power reactors using enriched uranium. Both research and power reactors are being built abroad and it is expected that more orders for the export of large power stations will arrive in the next year or so. The exhibits of all these firms at the Geneva industrial exhibition were described in ENGINEERING last 22 August (page 232), and a complete table of British reactor companies, with details of their activities, on 16 May (pages 618 and 619).

Research and Power Reactors in the United Kingdom

Name	Location. Owner	Date of start-up	Peak neutron flux	Maximum heat output	Moderator	Coolant	Fuel	Purpose
GLEEP	Harwell UKAEA	1947	$3{\cdot}7 \times 10^{10}$ thermal n/cm /sec	100 kW	Graphite	Air	Natural uranium metal oxide	Now routine graphite, uranium quality testing
BEPO	,,	1948	2×10^{12}	6 MW	Graphite	Air	Natural uranium	Isotope production and general radiation source, local heating
DIMPLE	,,	1954	About 10^8	100 Watts	Heavy water	None	Varies	Thermal reactor studies
LIDO	,,	1956	10^{12}	100 kW	Natural water	Natural water	Uranium 235	Thermal reactor, studies including shielding
DIDO	,,	1956	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Isotope production, neutron physics, nuclear reactor material studies
NERO		1957	About 10^8	Less than 100 watts	Graphite	None	Slightly enriched uranium	Investigations for advanced graphite-moderated reactors
PLUTO		1957	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Studies on nuclear reactor materials, isotope production
NEPTUNE	Harwell Admiralty	1957	About 10^8	Less than 100 watts	Light water	None	Enriched uranium	Studies on water-moderated core designs, with specific reference to a pressurised-water reactor for submarine propulsion
HAZEL	Harwell UKAEA	1958	About 10^6	Less than 1 watt	Heavy water	None	Uranyl fluoride (Uranium 235)	To obtain basic nuclear information on heavy-water-moderated, homogeneous systems
HTGC	Winfrith UKAEA	1959	—	—	Graphite	Nitrogen	Enriched uranium	Research on high-temperature gas-cooled system
MERLIN	Aldermaston A.E.I.	1958	10^{13}	5 MW	Water	Water	Enriched uranium	Irradiation and related studies
JASON	Hawker-Siddeley	—	$1{\cdot}5 \times 10^{11}$	10 kW	—	—	—	Research and training
Fast Reactor, Dounreay	Dounreay UKAEA	1958	—	60 MW	None	Sodium potassium alloy	Enriched uranium or plutonium	Fast reactor breeding studies
Submarine Prototype Reactor	,,	—	—	—	Water	Water	Enriched uranium	Prototype testing
DMTR (Pluto type)	,,	1958	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Studies on nuclear reactor materials
HERALD	Aldermaston UKAEA	1958	10^{14}	5 MW	Light water	Light water	Uranium 235	Neutron physics, radiochemical studies
Windscale† (2 reactors)	Cumberland UKAEA	1950	—	—	Graphite	Air	Natural uranium	Plutonium production
Calder "A" (2 reactors)	,,	1956	—	180 MW per reactor	Graphite	Carbon dioxide	Natural uranium	Plutonium and power production (92 MW)
Calder "B" (2 reactors)	,,	1958 (1st reactor)	—	180 MW per reactor	,,	,,	,,	Plutonium and power production (92 MW)
Chapelcross (2 stations, "A" and "B," 4 reactors)	Annan UKAEA	1959 (3 reactors)	—	180 MW per reactor	,,	,,	,,	Plutonium and power production (184 MW)
Berkeley (2 reactors)	Glos. CEGB	1961	$2{\cdot}14 \times 10^{13}$	555 MW per reactor	,,	,,	,,	Power production (275 MW)
Bradwell (2 reactors)	Essex CEGB	1961	$2{\cdot}68 \times 10^{13}$	531 MW per reactor	,,	,,	,,	Power production (300 MW)
Hunterston (2 reactors)	Ayrshire SSEB	1962	2×10^{13}	535 MW per reactor	,,	,,	,,	Power production (300 MW)
Hinkley Pt. (2 reactors)	Somerset CEGB	1962	4×10^{13}	950 MW per reactor	,,	,,	,,	Power production (500 MW)

Two further 500 MW stations are planned at Trawsfynydd and Dungeness.

Geneva Conference Reports

Surveys of subjects to be covered at the Geneva conference have been undertaken for ENGINEERING by the following authors. The majority are active in the United Kingdom Atomic Energy Authority.

Power Reactors	Mr. G. W. K. FORD
Research Reactors	Dr. V. S. CROCKER
Fusion Research (Pinch Effect)	Dr. A. A. WARE (A.E.I.)
(Other Devices)	Dr. R. J. BICKERTON
Propulsion, Shielding and Safety	Mr. B. T. PRICE
Engineering	Mr. R. P. KINSEY
Metallurgy	Mr. L. M. WYATT
Instrumentation	Mr. R. B. STEPHENS (Mullards)
Physics and Accelerators	Dr. M. J. POOLE, Dr. M. G. SOWERBY
Applications of Radio-isotopes	Mr. E. R. WIBLIN
Isotope Separation	Dr. H. KRONBERGER
Chemistry and Processing	Dr. R. HURST

United States

The following is a very brief outline summary of some of the principal activities supported by the United States Atomic Energy Commission towards developing peaceful applications of atomic energy. For more details, see the semi-annual reports of the USAEC, and especially the January 1958 issue, which covers the previous three years.

Uses of Radioisotopes

Industrial Applications.—Radiography, thickness gauging, density and liquid-level determination, oil-well logging, luminescent markers, chemical-reaction initiation, radiation preservation and sterilisation, long-lived batteries. These and other applications have been estimated to be worth 500 million dol annually to American industry in the form of improved products, faster and more accurate control, etc.

Medical and Agricultural Applications.—(1) Cancer studies—radiation therapy, metabolic studies, neutron therapy, diagnosis, tumour localisation. (2) General medicine—iron metabolism, blood-forming mechanisms, physiology of circulation, bone marrow properties, behaviour of drugs, cell metabolism, liver and kidney functions, etc. (3) Livestock studies—trace-element action, thyroid activity, animal nutrition, milk formation. (4) Agricultural studies—insecticide action, insect biochemistry, insect sterilisation by radiation, behaviour of plant growth regulators, fertiliser action, radiation mutations.

Basic Chemical and Physical Research.—(1) Chemistry—isotope exchange, reaction kinetics, surface reactions, diffusion, vapour pressure measurement, thermodynamic properties. (2) Physics—nuclear properties, length and time standards, instrumental techniques.

Power Reactor Development

In the development of nuclear reactors for the production of electricity, the USAEC has assumed the responsibility of developing a reactor concept to the stage of demonstrating that power can be obtained. Industry then participates in a joint programme to determine the large-scale feasibility and economics. The present state of development of the families of reactors being studied in the United States is indicated below. The 23 projects running or scheduled by 1964 will have a total capacity of 1,300 eMW.

Water-Cooled and Moderated.—Includes pressurised light water, pressurised heavy water, and boiling water types. Largest now operating is Shippingport PWR: output 60,000 ekW; first operated December, 1957. Others of 134,000 and 163,000 ekW under construction. Naval propulsion programme involves numerous pressurised systems. Nuclear merchant ship Savannah will contain this type. Two boiling-water reactors of 5,000 ekW now operating; capable of 3 or 4 times rated output. BWR of 180,000 ekW now under construction.

Organic-Cooled and Moderated.—Uses organic compound as coolant and moderator. Organic Moderated Reactor Experiment (OMRE) now operating at NRTS. Electrical generating equipment not installed. System to produce 1,500 ekW being designed.

Sodium-Cooled Thermal.—Sodium Reactor Experiment (SRE) now operating NRTS. Uses graphite as moderator. Similar system to produce 75,000 ekW being designed. Heavy-water moderated system of 10,000 ekW capacity under design.

Fast Breeder Systems.—Types under investigation: (1) Uranium 235 fuel, sodium coolant, heterogeneous fuel elements (SCBrR); (2) plutonium 239 fuel, sodium coolant, heterogeneous fuel elements; (3) molten plutonium fuel, sodium potassium alloy coolant. Experimental Breeder Reactor—2 (EBR-2) of type (1) under construction NRTS. Output 20,000 ekW. Will later be modified to type (2). Full-scale power reactor of type (1) with output 100,000 ekW under construction near Detroit, Michigan. First model type (3) being designed.

Homogeneous Systems.—Several experimental aqueous reactors operated; largest HRE-2 of 5,000 tkW in Oak Ridge. Full-scale power reactors being studied. Molten-salt systems studied.

Gas-Cooled, Graphite-Moderated.—Design study under way for 40,000 ekW plant using slightly enriched fuel.

Other Systems.—Several in various stages of development: (1) liquid-metal fuel, (2) plutonium recycle, (3) high temperature gas-cooled, (4) gas-cooled, heavy-water moderated.

Auxiliary Engineering.—Programmes in operation to study (1) power reactor safety; (2) behaviour of reactor materials and components under irradiation (in test reactors); (3) chemical processing of power-reactor fuel elements; (4) sanitary problems associated with waste disposal.

International Co-operation

International Atomic Energy Agency.—United States participates as member of Board of Governors. Has offered 5,000 kg uranium 235 for distribution through the Agency and will match contributions of other members. United States technical experts participate in IAEA missions. Educational facilities have been offered.

Bilateral Agreements for Co-operation.—Agreements in effect with 39 countries for co-operation in research and with 11 countries for co-operation in power-reactor development. Agreements include technical training in United States, facilities and financial assistance for research reactors, and equipment.

Euratom Agreement.—Co-operative power-reactor programme proposed involving installation of 1,000,000 ekW Euratom countries plus joint research programme.

Other Programmes.—(1) Participation in OEEC nuclear activities; (2) co-operation with Inter-American Nuclear Energy Commission of the Organisation of American States; (3) participation in development of plans for the Asian Nuclear Centre.

Basic Physical Sciences Research

Basic physical sciences research is conducted in USAEC installations and in other institutions through contracts. A few illustrative examples are given.

Physics.—Studies of high-energy particles, accelerator design, bubble chambers, nuclear cross-sections, nuclear structure, etc.

Controlled Thermonuclear Reactions.—Research at Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, Princeton University, and University of California Radiation Laboratory. Alternative approaches toward achieving controlled fusion being studied.

Chemistry.—Studies of trans-uranic elements, radiochemistry, radiation chemistry, chemical structures, high-temperature compounds, etc.

Metallurgy.—Studies of radiation damage, alloy development, metal oxidation, physical properties of metals, etc.

Major Research and Power Reactor Projects in the United States

Name or owner	Abbreviation for reactor system	Location	MW (electrical or thermal)	Operational or building
Experimental Breeder Reactor No. 1	EBR-1	Arco, Idaho	0·2e	Operational
Boiling Reactor Experiment	BORAX	Arco, Idaho	5e	Operational
Experimental Boiling Water Reactor	EBWR	Lemont, Ill.	5e	Operational
Sodium Reactor Experiment	SRE	Santa Susana, Cal.	7·5e	Operational
Vallecitos Boiling Water Reactor	BWR	Vallecitos, Cal.	5e	Operational
Organic Moderated Reactor Experiment	OMRE	Arco, Idaho	16t	Operational
Homogeneous Reactor Experiment	HRE	Oak Ridge, Tenn.	0·3e	Operational
Shippingport Pressurised Water Reactor	PWR	Shippingport, Pa.	60e	Operational
Commonwealth Edison Co.	BWR	Dresden, Ill.	180e	Building
Consolidated Edison Co.	PWR	Indian Point, N.Y.	273e	Building
Power Reactor Development Co.	SCBrR	Monroe, Mich.	100e	Building
Yankee Atomic Electric Co.	PWR	Rowe, Mass.	134e	Building
Experimental Breeder Reactor No. 2	EBR-2	Arco, Idaho	15e	Building
Rural Co-operative Power Association	BWRC	Elk River, Minn.	22e	Projected
City of Piqua	OMR	Piqua, Ohio	12·5e	Projected
Consumers Public Power District	SGR	Hallam, Neb.	81e	Projected
Chugach Electric Association	SDR	Anchorage, Al.	10e	Projected
Northern States Power Co.	BWRF	Sioux Falls, S. Dak.	66e	projected
Carolina-Virginia Nuclear Power Associates	PWR	Parr Shoals, S. Car.	19e	Projected
Pacific Gas and Electric Co.	BWR	Humboldt Bay, Cal.	50e	Projected
Pennsylvania Power and Light Co.	HRS	Pennsylvania	150e	Projected
East Central and Florida West Coast Groups	GCHWM	Florida	50e	Projected
USAEC Proposal	GCPR	—	—	Projected

Key to Reactor Systems.—EBR (experimental breeder reactor); BORAX (boiling reactor experiment); EBWR (experimental boiling-water reactor); SRE (sodium reactor experiment); BWR (boiling-water reactor); OMRE (organic moderated reactor experiment); HRE (homogeneous reactor experiment); PWR (pressurised-water reactor); SCBrR (sodium-cooled fast breeder reactor); BWRC (closed-circuit boiling-water reactor); OMR (organic-liquid cooled and moderated reactor); SGR (sodium-cooled graphite-moderated reactor); SDR (sodium-cooled heavy-water moderated reactor); BWRF (forced-circulation boiling-water reactor); HRS (homogeneous single-region slurry reactor); GCHWM (gas-cooled heavy-water moderated reactor); GCPR (gas-cooled power reactor); e (electrical); t (thermal).

Soviet Union

Development of nuclear energy in the U.S.S.R. has proceeded parallel to Western programmes. Seven reactor systems are being investigated; raw materials are abundant; radioactive isotopes have been widely applied to medical and industrial processes; and research in nuclear physics and thermonuclear problems has been extensive.

Resources

Deposits of uranium in Kazakhistan, Tadzhikistan, Eastern Siberia (Yakutsk), and Uzbekistan. Uranium and thorium also mined in the Urals. Ores available from mines in East Germany, Czechoslovakia, Hungary and Bulgaria.

Radioactive Isotopes

Application of radioactive isotopes in medicine include extensive work on cancer therapy. In industry, applications include study of furnace linings, machine wear, tracing, thickness gauging for clad materials, etc., and counting mass-produced items. The Soviet Union is known to have large-scale

Reactors in the Soviet Union

Name and type	Heat output	Electrical output	Fuel	Coolant	Moderator	Remarks
Academy of Sciences First Power Station, PWGrR	30 MW	5MW	En. U.	Light water	Graphite	Now been operating 4 years
Materials Testing Reactor	0·3 MW (flux 2×10^{13})	—	En. U.	Water	Graphite	Test reactor, isotopes
Reactor for Physical and Technical Research (RPT)	10 MW (flux 8×10^{13})	—	En. U.	Water	Water	Research isotopes
Heavy Water Reactor	0·5 MW (flux 2×10^{12})	—	Uranium	Heavy water	Heavy water	Research and isotopes
Beryllium Reactor Facility BRF	Zero energy	—	Uranium Oxide (U_3O_8) 10 per cent U235	Various (including water)	Beryllium	Studies of beryllium as moderator (ENGRG. 7 June, 1957, page 731)
Project 1 (or 2) (2 or 4 reactors), PWGR	1,150 MW	400 MW	Slight En.U.	Light water	Graphite	Steam superheated in reactor. 35 per cent efficiency. Four 100 MW turbines
Project 2 (or 1), PWR	1,520 MW	420 MW	En. U.	Light water	Light water	Three water circuits per reactor, each driving a 70 MW turbine
Project 3, GCDR	—	300 MW?	Nat. U.	Carbon dioxide	Heavy water	Superheated steam will drive turbines of between 50 and 100 MW each
Experiment 1(or 2), SGR	50 MW?	50 MW?	En. U.	Liquid sodium	Graphite	For investigating problems of heat transfer from reactor to generating plant
Experiment 2 (or 1) BWR	70 MW?	70 MW?	En. U.	Light water	Light water	For investigating problems of driving turbine directly with reactor coolant
Experiment 3 BDHTBrR (2 region)	—	—	Th-U233 cycle (as salts in solution)	Heavy water	Heavy water	Breeding studies
Experiment 4 (FBR) (2 region)	—	—	U238-Pu cycle	Liquid sodium	—	Breeding studies

Reactor systems: PWGrR (pressurised-water graphite moderated reactor); PWR (pressurised-water reactor); GCDR (gas-cooled heavy-water moderated reactor); SGR (sodium-cooled graphite-moderated reactor); BWR (boiling-water reactor); BDHTBrR (boiling heavy-water homogeneous thermal breeder reactor); FBR (fast breeder reactor).

Continuing Atomic Review

isotope separation plants, both for producing the fissile isotope of uranium, and for separating fission products including plutonium.

Research

Extensive work on constitution of atomic nucleus using 10 GeV proton synchrotron and other accelerators, including meson and catalysed fusion studies, a 50 GeV proton synchrotron is building. Advanced work on thermonuclear reactions using pinch effect in straight and toroidal devices.

Reactors and Propulsion

Nuclear power stations are to be built mainly in European Russia and the Ukraine, since other parts of the Soviet Union are well supplied with conventional energy resources. The seven different reactor systems to be employed in power stations have recently been described by Nikolai Nikolayev, deputy head of the Central Board for Atomic Energy Development, on whose statement together with a report submitted to the United Nations Economic and Social Council the accompanying table is based. More extensive details of Projects 1 and 2 and of four experimental plants were given in ENGINEERING, 30 August, 1957 (pages 283 and 284). A 16,000 ton icebreaker, Lenin, to be powered by a pressurised-water reactor propulsion unit has been launched.

France

France has an extensive atomic energy programme based on "La voie du plutonium," and is well endowed with nuclear materials. A number of power and plutonium reactor projects have been undertaken, under the auspices of the Commissariat à l'Energie Atomique and Electricité de France, and a nuclear-powered submarine is at present under construction. Research is extensively carried out by both the bodies mentioned, and includes thermonuclear studies. France may independently or as a member of Euratom build an isotope separation plant for the production of enriched uranium, and a project has been undertaken in the Pyrenees for the manufacture of heavy water by electrolysis. Full details of the French programme appeared in ENGINEERING on 9 August (page 188) and 16 August (page 217), 1957. Information published below is taken from C.E.A. and United Kingdom Board of Trade documents.

Resources

Raw materials are plentiful. Metropolitan resources of uranium are estimated at from 50,000 to 100,000 tons of metal (10,000 tons proved by direct working). Considerable reserves of uranium are also reported in the superphosphate ores of North Africa. In Madagascar established reserves include 1,000 tons of urano-thorianite, containing 10 to 12 per cent of uranium and 60 to 70 per cent of thorium. Planned annual output of chemical concentration plants at Gueugnon (50,000 tons ore), Ecarpière (300,000 tons ore) and Bessines (200,000 tons ore) amount to 1,150 tons of uranium concentrates. Total planned production of uranium was to be 500 tons a year in 1958; 1,000 tons in 1961; 2,500 tons in 1970; and 3,000 tons in 1975, but recently it has been decided to limit production.

Research

Research establishments are at Châtillon (Centre d'Études Nucléaires de Fontenay aux Roses), Saclay (corresponds to AERE, Harwell) and Grenoble. Equipment includes two Van de Graeff accelerators, a cyclotron, a linear accelerator (at Châtillon) and a new 2·5 GeV proton synchrotron of mean diameter 17 metres known as Saturne (Saclay). Research reactors are listed in the accompanying table. A straight-tube thermonuclear device has been built at Châtillon.

Reactors and Propulsion

A considerable number of research and power reactors are operating, under construction or projected, as listed, in the accompanying table. In particular a gas-cooled power-producing prototype using beryllium oxide as moderator and natural uranium as fuel is to be studied. A nuclear-powered submarine is under construction and will be fitted with a reactor cooled and moderated by pressurised heavy water. The United States is to provide enriched uranium for this purpose.

Canada

Canada's part in the development of atomic energy has been closely linked with work in Britain and the United States, particularly in the early stages. It may be said that of the three reactor systems that appeared promising from the first—the pressurised water, the gas-cooled and the heavy-water moderated—America and Britain undertook development of the first and second, and Canada chose the third. Canada's vast uranium resources continue to give her a leading place, though her conventional energy resources are such as to make her independent of nuclear power—at least for the time being. The following notes are taken from material supplied by Atomic Energy of Canada Limited, and from a Central Office of Information Survey. Atomic Energy of Canada Limited is a holding company, formed by Act of the Canadian Parliament to hold the stock of Nuclear Research Limited, which controls the Chalk River research and development project, and of Eldorado Mining and Refining Limited, which controls the disposal of all uranium ores and concentrates produced by private companies.

Resources

In 1957 Canada produced 6,687 tons of uranium and expects to produce 13,000 tons in 1958; by 1959 production may reach 15,500 tons. The main mining areas are Great Bear Lake (North-West Territories), Beaver Lodge (Northern Saskatchewan), Blind River (Ontario), and Bancroft (Ontario). Most of the uranium is delivered to the USAEC, but there are also contracts with the United Kingdom. A plant to be built in the Blind River area will produce when it begins operating in 1959 100 to 200 tons of thorium salts annually, a quantity about equal to current world production.

Radioactive Isotopes

Canada has pioneered the production of radioactive isotopes of high specific activity, particularly cobalt 60 for use in cancer treatment units. Many different isotopes are produced for use in medicine, agriculture and industry and are distributed throughout the world.

Reactors

Atomic Energy of Canada Limited operates four research reactors (listed in the table on the facing page) at its main establishment at Chalk River, Ontario. Two power projects are in progress (also listed), known as NPD and CANDU. Construction of NPD was suspended in 1957 to incorporate improved features in the design, but was resumed this year. The project is being carried out with the co-operation of the Hydro-Electric Power Commission of Ontario and the Canadian General Electric Company.

International Agreements

Member of IAEA. Collaboration with United Kingdom and United States since early 1940's. In the past year Canada has signed agreements with West Germany and Switzerland. Other bilateral agreements are expected. Under the Colombo plan, Canada is building in India a reactor similar to NRX known as the Canada-India reactor (CIR), and is also contributing training facilities and technical assistance.

India

The Indian Atomic Energy Commission was established in 1948, but only received full executive and financial powers in 1958. The Commission has its main establishment at Trombay near Bombay, where there is a pool reactor and two other research reactors are under construction.

Resources

Total reserves of thorium in India's monazite sands are estimated at 500,000 tons easily extracted (300,000 tons in concentrations above 10 per cent). India is a leading producer of beryl the source of the moderating and low neutron-absorption material beryllium. Plants for the extraction and processing of uranium, thorium and beryllium are already in existence or under construction. A plant at Nangal is to produce 10 to 20 tons of heavy water annually together with 340,000 tons of nitrogenous fertiliser. The production of graphite from petroleum coke and coal tar pitch and of zirconium is being studied.

Reactors

India's first nuclear reactor, ASPARA, became critical in 1956. With a power level of 1,000 kW, it is of pool type, similar to LIDO, using ordinary water as moderator and enriched uranium fuel elements supplied by the UKAEA. It is employed for irradia-

Reactors in France

Name	Location	Date critical	Type	Moderator	Output		Maximum flux	Fuel	Reflector	Coolant	Purpose
					Thermal	Electrical					
El.1 (ZOE)	Châtilion	1948	Thermal	Heavy water	150 kW	—	10^{12}	Nat. U 1·9 T.	Graphite	Heavy water	Experience, radioisotope production
TRITON	Châtillon	1959	Pool	Heavy or light water	1,000 kW	—	10^{13}	En. U 20 per cent	—	Water	Shielding materials studies
MINERVE	Châtillon	1959	Pool	Light water	Low power	—	—	En. U 20 per cent	—	Water	Materials and engineering studies
El.2	Saclay	1952	Thermal	Heavy water	2,000 kW	—	10^{13}	Nat. U 3 T.	Graphite	Carbon dioxide at 7 atm.	Experience, radioisotope production
AQUILON	Saclay	1956	Thermal	Heavy water	Zero energy	—	—	Nat. U	Graphite	—	Lattice Studies
El.3	Saclay	1957	Thermal	Heavy water	15 MW	—	10^{14}	U of Low enrichment	Heavy water and graphite	Heavy water. Forced circ.	High flux, materials testing
PROSERPINE	Saclay	17.3.58	Homogeneous	—	Low power	—	5×10^{7}	Pu sulphate dissolved in water	Beryllium oxide and graphite	—	Experience
MELUSINE	Genoble	1.7.58	Pool with 2 working positions	Water	1·2 MW	—	10^{12}	En. U 20 per cent	—	Water. Forced circ.	Fundamental studies in nuclear physics
G1	Marcoule	1956	Thermal	Graphite	40 MW	5 MW (recovered)	5×10^{12}	Nat. U 100 T.	Graphite	Air at atmospheric pressure	Plutonium production
G2	Marcoule	21.7.58	Thermal	Graphite	150 MW	25 to 30 MW	$2 \cdot 5 \times 10^{12}$	Nat. U 100 T.	Graphite	Carbon dioxide at 15 atm.	Plutonium production Prototype power station (Pre-stressed concrete pressure vessels)
G3	Marcoule	1958/59	Thermal	Graphite	150 MW	25 to 30 MW	$2 \cdot 5 \times 10^{12}$	Nat. U 100 T.	Graphite	Carbon dioxide at 15 atm.	Plutonium production Prototype power station (Pre-stressed concrete pressure vessels)
EDF.1 (followed by EDF.2 and EDF.3)	Avoine	End of 1959	Thermal	Graphite	300 MW	60 MW	$4 \cdot 5 \times 10^{13}$	Nat. U	Graphite	Carbon dioxide at 25 atm.	Power and Pu production
ALIZE	Saclay	1959	Thermal	Water	Zero energy	—	—	En. U	—	Water	Lattice study
PEGASE	New site	—	Thermal	Beryllium Oxide	—	—	—	Highly En. U	—	Water (core) Gas (test element)	Fuel testing
BRENDA	New site	—	High temperature	Beryllium Oxide	12 to 17 MW	—	8×10^{13}	En. U	—	Gas	Producing gas at high temp. 700° C
RAPSODIE	New site	—	Fast	—	2 projects: 1 MW and 10 MW	—	—	En. U and Pu alloy	—	Liquid sodium	Fast neutron irradiation and Breeding studies

Reactors in Canada

Name	Location	Operating date	Type	Output		Fuel	Coolant	Moderator	Max. flux	Purpose
				Thermal	Electrical					
ZEEP	Chalk River, Ontario	1945	Thermal	10 watts nom. 250 watts achieved			Heavy water	Heavy water	10^7 or ^{8}	Materials testing and research Lattice experiments
NRX	Chalk River	1947	Thermal	40 MW ..		Nat. U	Heavy water	Heavy water	$6{\cdot}8 \times 10^{13}$	Materials and loop testing; Isotope production; Pu production
NRU	Chalk River	1957	Thermal	200 MW ..		Nat. U (aluminium sheaths)	Heavy water	Heavy water	3×10^{14}	Materials and loop testing; Isotope production; Pu production
PTR (Pool Test Reactor)	Chalk River	1957	Thermal			En. U	Light water	Light water (Graphite reflector)	2×10^{11}	Research on shielding and fuels
ZEEP-2 Planned			Thermal							Lattice experiments for CANDU Larger than ZEEP
NPD (Nuclear Power Demonstration)	Rolphton, Ontario	1961	Thermal		20 MW ..	Nat. U	Heavy water	Heavy water	$1{\cdot}1 \times 10^{14}$	Feasibility of power production, not intended to be economic
CANDU (Canadian Deuterium Uranium) Design study		1963?	Thermal		200 MW	Nat. U oxide (sintered pellets sheathed in Zircaloy-2	Heavy water	Heavy water		Economic power production without credit for Pu.

tion experiments and isotope production, including small quantities of radioactive sulphur, phosphorus, cobalt and iodine. Work on the high-flux reactor of NRX type, the Canada-India reactor, being built for India by the Canadian Government began in 1956 and is expected to be completed in 1959. Work on a zero-energy reactor for lattice and assembly investigations, ZERLINA began in 1957; the reactor is expected to start operating towards the end of this year. The Government is considering construction of one or more nuclear power stations in the near future in areas remote from the existing coal fields in Bihar and West Bengal. One may be in operation by 1962. A study of a power reactor of 10 to 20 MW with beryllium oxide as moderator is being carried out at Trombay.

Australia

The Australian Atomic Energy Commission was set up in 1953. The country is well supplied with uranium deposits and has a materials testing reactor in operation. There is considerable collaboration with the United Kingdom, United States and Canada.

Resources

The main deposits of uranium are at Rum Jungle in the Northern Territory, Radium Mill in South Australia and Mary Kathleen in North-West Queensland. When this last undertaking comes into full operation the total Australian output will be about 1,000 tons of uranium oxide a year. Monazite containing thorium is produced as a byproduct of mining operations in Western Australia.

Reactors

The high-flux Australian reactor HIFAR was inaugurated this year. A modified version of DIDO, it is rated at 10 MW (heat) and uses heavy water as moderator and primary coolant and ordinary water as secondary coolant. Enriched uranium-aluminium alloy plates serve as fuel. It is intended for material and loop studies in the development of nuclear power in Australian conditions and the production of radioisotopes.

Work has also started on two power reactor systems. One is a high-temperature gas-cooled system directed towards the development of a thermal breeder reactor with thorium as fertile material and a highly enriched fuel element operating as much above 600° C as possible. Beryllia, beryllium and graphite are being considered as moderators for the system. The second is a reactor system with liquid metal, using sodium slurry as coolant and fuel carrier with beryllium as moderator. A further major part of the programme is a chemical processing project. It is considered that nuclear power stations would be particularly suitable for areas remote from coal deposits, such as South Australia, Northern Queensland and the Northern Territory, though lack of cooling water may present a problem. Nuclear power is under consideration for a 15 MW station at Darwin, Northern Territory (Federal Government), and for a 60 MW station (Mount Isa Mines Limited).

South Africa

South Africa is mainly important in the nuclear field because of its extensive uranium deposits. An Atomic Energy Board was set up in 1949 to supervise nuclear development and to promote prospecting, mining and refining of uranium ores.

Resources

South African uranium reserves are the largest known in the world (outside the Soviet bloc). They are, however, of a lower grade than those of the United States and Canada, and yield a ½ lb to 1 lb of oxide per ton of ore. The annual rate at which the Combined Development Agency, representing the United Kingdom and United States, can purchase uranium from South Africa from this year is set at 6,200 tons tapering off from the end of 1963. This represents the bulk of, if not all, the yearly output that can be expected.

International Bodies

International Atomic Energy Agency

In December, 1954, the United Nations General Assembly unanimously adopted a resolution calling for the setting up of an International Atomic Energy Agency. The sponsors, all of whom are concerned with producing nuclear energy or supplying materials, were Australia, Belgium, Canada, France, South Africa, the United Kingdom and the United States. The objectives of the Agency are: " to seek to accelerate and enlarge the contributions of atomic energy to the peace, health and prosperity of the world." The Agency is intended to assist and encourage research; provide materials, services and equipment; foster the exchange of information; establish safeguards against the use for military purposes of fissile material made available through it; establish standards of safety; and build any plant or equipment necessary to carry out its objectives.

The Agency was set up in Vienna in 1957. Membership is open to all United Nations countries but any other nation may apply to join. The work of IAEA is carried out by a board of 23 governors on which the United Kingdom as one of the five major atom powers will have a permanent seat. In its first eight months of operation offers of 5·150 kg of uranium 235 were received from member states. An international trading programme will come into operation in the autumn of this year. A technical library has been set up containing over 40,000 publications and documents all given by member countries. The Agency's budget for 1959 will be about 5·25 million dol. Two IAEA international conferences have been organised, the second will be held at Vienna in September.

European Nuclear Energy Agency (OEEC)

In April, 1956, the Commission for Energy of OEEC set up a Working Party on Nuclear Energy to explore means of technical, financial and economic co-operation among OEEC countries in the peaceful uses of atomic energy. The working party prepared a report on the basis of which the special committee was established. The members of the special committee are the 17 OEEC countries, including the six Euratom countries, which accepted it as compatible with their own separate activities, plus United States and Canada. The committee has the task of establishing security control, setting up joint undertakings and taking interim measures to secure a joint free market in nuclear material and equipment. A Steering Committee for Nuclear Energy was set up in July, 1956, to work out joint projects and arrange for the setting up of a European Nuclear Energy Agency. The aims of the Agency are to collect and distribute information; work out common regulations or basic standards so that national regulations can be harmonised; provide services and advice to countries needing these. The Agency will cooperate closely with Euratom and will collaborate with other international organisations.

In December, 1957, OEEC formed its first joint undertaking, an international company, Eurochemic, which is to build a plant for the chemical processing of irradiated fuels at Mol in Belgium. Other joint projects with which the Agency is concerned are for a boiling-water reactor at Halden (Norway) and possibly a homogeneous aqueous reactor at Winfrith Heath.

Euratom

Euratom, like the European Economic Community (European Common Market) originated in the Messina Conference of June, 1955, in which the " Six "—France, Italy, W. Germany, Holland, Belgium and Luxembourg took part. It was embodied in the Rome Treaties which came into force on 1 January, 1958. The distinguishing feature of Euratom is its supra-national character. The member governments have vested certain powers in a commission which will wield executive power. The other main institutions are a Council of Ministers; a Common Assembly (shared with the Economic Community and the Coal and Steel Community); and a Court of Justice (also shared) to consider alleged infringements of the provisions of the Rome Treaty.

The commission will co-ordinate research activities and facilitate the exchange of research results, establish training facilities and take part as shareholder in projects that might prove too expensive and risky for public and private enterprise. The Commission will also maintain a voluntary patent pool and act to prevent restricted use of patents for monopoly purposes. Investment will remain the responsibility of public and private concerns but the commission will supply information and if need be financial assistance, but will not direct or control investment.

The commission will have an option to buy all non-committed supplies of ore and nuclear fuels from Euratom members. It will supply by lease or sale nuclear material acquired in or outside the Euratom countries for all *bona fide* purposes of public or private enterprises. The Euratom commission will have strict powers of inspection of all nuclear plants. Finally, Euratom will establish a common free market for nuclear materials and equipment of the six member countries. The president of the Euratom Commission is M. Louis Armand, and its headquarters, pending a decision on their final location are at 23 Rue Belliard, Brussels.

CERN

The European Organisation for Nuclear Research, known by its French initials as CERN, came into existence in September, 1954. It originated in a resolution at the fifth Unesco general conference in June, 1950. The members are Belgium Denmark, France, Federal Republic of W. Germany, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia. CERN is intended to plan collaboration between the member states in pure research and has an international laboratory at Meyrin near Geneva for this purpose. CERN'S main items of equipment will be two accelerators—a proton-synchroton of 25 to 30 GeV and a synchro-cyclotron of 600 MeV. The council has set up committees to deal with administration, scientific policy and finance. Apart from its own research activities, CERN has arranged a number of international conferences.

Joint Nuclear Research Institute

Corresponding to CERN in the communist countries is the Joint Nuclear Research Institute situated at Dubna on the Volga. It is an international body and the signatories to the agreement establishing it are Albania, Bulgaria, Hungary, East Germany, China, Northern Korea, Mongolia, Poland, Roumania, Czechoslovakia and the Soviet Union. The institute embraces four laboratories concerned with: nuclear problems, high energies, neutron physics and theoretical physics. Work is at present mainly grouped round two accelerators at 10 GeV proton synchrotron and a 680 MeV synchro-cyclotron. A 50 GeV proton synchrotron is to be built, but it is not certain whether this machine will be operated by the institute. A pulsing reactor, providing sudden intense bursts of neutrons, is also believed to be under construction. The director (at least until the end of last year) is Academician D. I. Blokhintsev.

This series of summaries will be continued at a later date when reference to the atomic energy programmes of Sweden, Norway, Denmark, Holland, Italy, Japan and certain other countries will be made.

Special Article

Candidates for Farnborough

BRITAIN'S TRANSPORT AIRCRAFT

The air display at Farnborough which opens next week comes a little too early for a full array of this year's crop of new airliners. The 60/75 seat de Havilland Comet 4 will be there, marking the imminent re-entry of B.O.A.C. into the field of jet travel. A full description of the Comet's intensive development has already appeared in ENGINEERING (2 May '58, p, 554). Deliveries of the Comet 4 are due to begin immediately after the Farnborough show ends, and B.O.A.C. plan to introduce the Comet 4 on the London-New York route before the end of the year.

The Comet 3B will also fly at Farnborough, fitted with the shorter-span wing of the shorter-range faster-cruising larger-capacity Continental Comet 4B, which B.E.A. have on order. Thrust reversers are fitted to the Rolls-Royce Avon RA29 jets of the Comet 3B, and the pilot is expected to demonstrate how they shorten the aircraft's landing run.

For the first time Britain's " VTOL " airliner, the Fairey Rotodyne, will fly at Farnborough—and it is expected that by then it will be shown with a retractable undercarriage and with silencers fitted on the rotor-blade tip jets. The 48 seat Rotodyne (ENGRG., 13 June '58, p. 750), which takes off as a reaction-driven helicopter and cruises as a fixed-wing turbo-prop aircraft, is designed to make genuine city-centre to city-centre travel an attractive commercial proposition. It is powered by Napier Elands. The Rotodyne's future now appears to be assured: the Kaman Aircraft Corporation, Connecticut, have signed an agreement with Fairey for the manufacture and sale of the Rotodyne in America; and it is understood that the U.S. Army are very interested in the machine.

The Fairey Rotodyne " city-centre " airliner, seen here with fixed undercarriage, may be built in America under licence.

A new 43-seat turbo-prop version of the Handley Page Herald—a straight-forward local-service airliner offering modern standards of pressurised comfort, but capable of operating from " out-back " airfields—is also to fly. With " fail-safe " structure, and powered by two Rolls-Royce Darts, the Dart Herald cruises at 275 m.p.h. The two most interesting turbo-prop débutantes are not, however, coming out until the end of the year—we refer to the Vickers Vanguard and the Armstrong Whitworth Argosy —although there will be on view a full-scale section of the fuselage of the Argosy, showing the versatility of its cabin arrangement and the " fail-safe " fuselage structure.

The Handley Page Dart Herald local-service airliner.

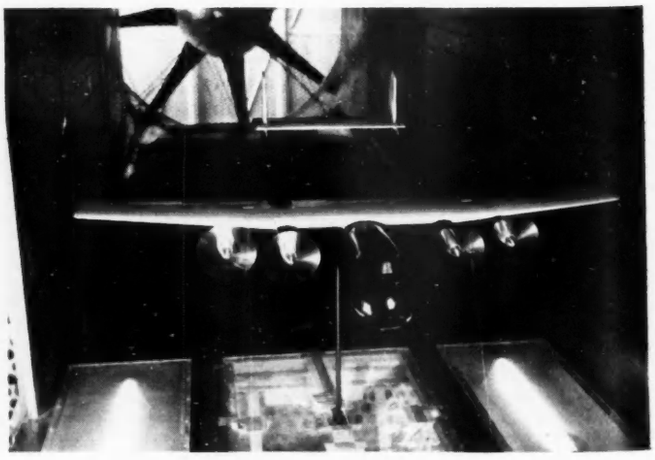
VANGUARD

Flexibility of layout, quick turn-round time, and economical high-speed cruising (well over 400 m.p.h.) over a wide band of altitude are the keynotes of the Vickers Vanguard, which is powered by four 5,315 s.h.p. Rolls-Royce Tyne propeller turbines. The ability to operate at high speed at heights as low as 5,000 ft, as well as at optimum altitude, characteristic of the turbo-prop aircraft, is an important asset on routes where air traffic congestion may dictate the altitude at which the aircraft has to fly.

The Mark 1 version is designed to carry 76 first-class, 86 mixed-class, or 93 tourist-class passengers, plus baggage and freight, over medium and long-range routes; it can carry full payload on stages up to 2,600 miles. Recently, Vickers have announced a strengthened Mark 2 version for short to medium distances capable of carrying an additional 4,000 lb payload which, they believe, should give the Vanguard the lowest seat-mile costs ever offered to the airlines. Carrying 139 passengers in a " thrift " class cabin layout, seated six abreast at 34 in seat pitch, the Mark 2 Vanguard, Vickers claim, could

(Below left) The Tyne-powered Vickers Vanguard nears completion at Weybridge.

(Below right) The configuration of the Armstrong-Whitworth freighter/coach aircraft—also in the final assembly stage — is clearly shown by the powered wind tunnel model.



reduce European air fares by up to 50 per cent. The structural modifications necessary to permit this increased payload can be incorporated on any aircraft after the twelfth on the production line; but whether B.E.A. and T.C.A.—who each have 20 Vanguards on order—will decide to take up the shorter-range version is not yet known. For operation on the longer stages the Mark 1 aircraft remains the better proposition.

The Vanguard fuselage is of " double-bubble " form, passengers being carried on the upper deck, the whole of the pressurised underfloor-space—1,360 cu. ft—being available for freight and baggage. Among the features designed to expedite turn-round time—particularly important for the inter-city operations that are common on the North American continent—are the siting of the entrance doors for rapid loading—two for the passengers on the port side, forward and aft, with built-in steps, while crew and freight doors, galley servicing doors, and so on, are on the starboard side. The freight doors, about 5 ft 6 in wide and nearly 4 ft deep, allow simultaneous loading and unloading. Single-point pressure-fuelling allows the up-take of fuel at the rate of 600 gal per min. Because the Vanguard is intended for operation from comparatively small airfields, double-wheel main undercarriage units have been selected in preference to bogies, to minimise the turning circle.

Structurally, the main point of interest of the Vanguard is the " fail-safe " torsion box comprising the main wing member, which is built up from integrally-stiffened top and bottom " planks " cut from solid slab, and three vertical webs. This design provides that, should any part of the torsion box fail, the load can still be taken by the remaining portion. The fuselage, of conventional semi-monocoque form, also incorporates " fail-safe " characteristics in that alternative stress paths are offered in regions of high stress around doorway openings, windows, etc.

ARGOSY

The A.W. 650 Argosy freighter-passenger aircraft which is now nearing completion at the Bitteswell works of its designers, Sir W. G. Armstrong Whitworth (Aircraft) Limited, Coventry, is an exciting aircraft because it opens up new possibilities for the aircraft operators. Only the fringe of the freighting market has as yet been tapped by the airlines—partly because the aircraft which they are currently operating were not designed for the job and are not economical. If the Argosy lives up to its paper performance, the constructors believe that it will be possible to slash air-freighting costs dramatically, and to appeal to a much wider market. There is, however, much pioneering to be done in order to convert industry generally to the advantages of air freighting—and therefore Armstrong Whitworth have aimed at a flexible design which is attractive also as a medium-range passenger carrier, cruising at about 300 m.p.h. in pressurised " turbo-prop " comfort. The aircraft also can readily be adapted, on the production line, to military needs.

The basic A.W. 650 is a four-engine machine, powered by the well-proved 2,100 h.p. Rolls-Royce Dart propeller turbines—but because, for certain long-range freighting duties, the more modern 4,695 h.p. Tyne propeller turbines may give better economy, a twin-Tyne version (A.W. 651) has also been proposed, and the basic configuration has been chosen to give adequate clearance for the larger propellers of the Tyne powerplants.

For rapid freight-loading and minimum turn-round time, the twin-boom layout of the Argosy and its derivatives is a " must "—enabling entire nose and rear portions of the fuselage to be hinged and opened up sideways so that freight can be off-loaded at one end while a further batch is loaded on at the other end. In the military versions, A.W. 660 (4 Darts) and 661 (2 Tynes), a different type of rear fuselage would be fitted, incorporating integral door and loading ramp, and also a door to permit stores-dropping during flight. All the variants mentioned so far have pressurised cabins. Two further versions planned have much wider unpressurised double-deck fuselages for car-ferry duties, and as a short-range " air bus " seating 126 passengers.

The de Havilland Comet 4 airliner is expected to be in service between London and New York before the end of the year.

Turning back to the ten Argosys which are already in production—the first is planned to fly in November, and so far Armstrong Whitworth have been notably successful in their time scheduling and in their production planning. Just over two years from conception to completion of a large and very carefully engineered aircraft is a record feat. We give below the principal particulars of the Argosy. Maximum take-off weight, 82,000 lb; structural weight, 27,580 lb; span, 115 ft; length, 86 ft 9 in; height, 27 ft; gross wing area, 1,458 sq. ft; aspect ratio, 9·07; hold volume (usable), 2,630 cu. ft; hold length, 46 ft 10¾ in; width, 10 ft; clear interior height, 80 in plus; floor height above ground (aircraft loaded), 4 ft; minimum door dimensions, 100 in by 80 in. *Performance*—cruising speed (14,000 r.p.m.), 296 m.p.h.; range with maximum payload, 27,000 lb, 800 statute miles; range with 20,000 lb payload, 1,600 statute miles; maximum range with 9,400 lb payload, 2,800 statute miles (no reserves); take-off field length, sea level standard atmosphere, 4,050 ft; take-off field length, altitude 4,000 ft, in the tropics, 5,500 ft.

THE OLDER GENERATION

Of the older generation of British airliners, the Viscount, aptly timed, well engineered, and aggressively marketed, has had an unprecedented success; 330 are already in service, and many more are on order. The latest Viscount 810 series, with a cruising speed of 365 m.p.h., is represented at Farnborough by one of Continental Air Lines 812's in the flying display as well as by one of Lufthansa's 814 Viscounts in the static park.

Because the world's airline operators have succumbed rather prematurely to the attractions of the jet aircraft—it now seems doubtful whether the traffic potential is adequate to make the large jet airliners a profitable proposition—the Bristol Britannia has not met with the sales success that it deserves; nevertheless, 76 machines have already been ordered, including military contracts, and at the moment Britannias seem to be gaining ground. Their comfort, speed and regularity are drawing the transatlantic trade to their operators in this sphere, El Al, and B.O.A.C. and Canadian Pacific Airlines. El Al have ordered a fourth Britannia to add to their

Continuing **Britain's Transport Aircraft**

fleet of three, and Cubana de Aviacion have doubled their order from two to four. A new customer is Air Charter Limited, who are taking delivery of a 307 for general charter and trooping work this September; they are also interested in the adaption of the Britannia for car-ferry duties.

THE 1958 HELICOPTERS

In addition to the prototype Fairey Rotodyne airliner, three more new helicopters are flying at the display of the Society of British Aircraft Constructors this year—the prototype Westland Westminster flying crane, the Bristol 192 military helicopter and the five-seat Saunders-Roe P531 general-purpose machine. In contrast to the reaction-driven rotor of the Rotodyne, these three turbine-powered machines all have shaft drives.

THE WESTMINSTER

It is in the special-purpose role rather than as a commercial machine that the helicopter has so far justified its existence—and amply so; for rescue duties, for liaison with inaccessible places, and for manoeuvring heavy equipment into areas where no other mechanical means of transport can penetrate.

The Westminster, designed and constructed as a private venture by Westland Aircraft Limited, Yeovil, falls in this last category. Described by its makers as a crane/transporter, it will handle a disposable load of more than 6 tons. Used as a military transport helicopter, the Westminster is able to carry heavy field equipment and atomic missiles both externally and within the open welded-steel tube framework of its fuselage; with sections of the fuselage partly covered, it can also transport Commando troops. In its civil applications it has obvious possibilities in constructional engineering, and a covered-fuselage version can be made available for carrying up to 46 passengers.

The Westminster is powered by two Napier Eland turbine engines specially modified for this application by the removal of the reduction gear and the provision of a rear drive to the two-stage rotor gearbox. (This latter, together with the rotor head and blade system, are well-proven Sikorsky S56 components.) In the production version, 3,500 h.p. Elands will be installed; the present version is somewhat less powerful.

The diameter of the five-blade rotor is 72 ft, and the fuselage is 89 ft 3½ in long. The Westminster cruises at 115 m.p.h. and has a range of 180 miles with a 4 ton payload.

BRISTOL 192

In production for the Royal Air Force, the Bristol 192, made by Bristol Aircraft Limited at their Weston-super-Mare division, is said to be western Europe's biggest military helicopter. It is designed for troop and freight transport, ambulance duties, and search and rescue operations.

Like its forerunner, the Bristol 173, the Bristol 192 has a tandem-rotor configuration. The two four-blade rotors are driven by two 1,300 s.h.p. Napier Gazelle free-turbine engines, interconnected by a shaft in order to synchronise the rotors and to permit both rotors to be driven by one engine in the event of a failure.

The Bristol 192 has an all-up weight of 18,000 lb, and can carry 18 troops over a range of over 280 statute miles, or 25 troops over short distances. As a freighter, the helicopter will carry a maximum concentrated load of 4,000 lb or a maximum distributed load of 6,000 lb. In the ambulance role, eight stretcher cases can be carried, with two seats for medical attendants or "sitting wounded." The aircraft cruises at a speed of 138 m.p.h.

SAUNDERS-ROE P531

Another private-venture helicopter is the new P531 designed and constructed by Saunders-Roe Limited, Eastleigh—a small lightweight five-seat general-purpose helicopter with a good performance, sufficiently compact to be flown safely into and out of very small landing sites. Powered by a 425 s.h.p. Blackburn Turmo 600 series free-turbine engine, the P531 has an all-up weight of 3,800 lb, and cruises at 115 m.p.h. With normal tankage, the maximum range is 240 miles, and with an additional long-range tank, 320 miles.

The four-blade rotor has the same diameter as that of the Skeeter, 32 ft 6 in; the overall length of the aircraft, blades folded, is 29 ft, and width 8 ft 6 in; it is 9 ft 6 in high.

Two single seats are arranged at the front of the cabin and, behind these, a single bench-type seat for three passengers which can be folded flat against the cabin bulkhead to leave a clear space for freight. In the ambulance role, two standard service stretchers occupy this space, and the medical attendant occupies the seat, which is reversible, next to the pilot.

A lightweight air-operated Lucas hoist is fitted for rescue operations. External loads can be carried in slings or in a cargo net beneath the fuselage. In the trainer version, full instrument-flying facilities will be available. Provision is made for the installation of autostabiliser/auto pilot, cabin heating and de-icing. Either wheels, skids or floats can be fitted.

For maximum accessibility and minimum maintenance problems, the entire engine transmission and rotor systems are mounted above the structure, and all controls and electrics are easily reached through large hinged panels running the length of the forward fuselage sides. The nose is hinged to give complete access to the instrument panel, rudder controls and radio.

The airframe and transmission/rotor systems have been deliberately designed to accept the much higher outputs of the Turmo 600 Series engines now being developed. They are capable of absorbing powers up to 650 s.h.p. and will allow any power unit in the 800 to 1,000 s.h.p. category to be installed. Such a power unit would be derated to standard atmosphere conditions, and would thus make the P531 capable of operating in any part of the world without suffering the payload limitations in hot climates or in mountainous regions that have so often been the bugbear of helicopter operations in the past.

The Westland Westminster "flying crane."

The Saunders-Roe P531 five-seat general-purpose helicopter.

The Bristol 192 military-transport helicopter.

"What's on at Farnborough"

At the Society of British Aircraft Constructors' flying display at Farnborough next week (2 to 7 September), the Short SC1 vertical take-off research aircraft can be seen in the static park—but not, unfortunately, in the air. However, the new Blackburn NA39 naval strike bomber will be flying, and other newcomers to Farnborough, described in the adjacent articles, include three helicopters—Bristol 192, Westminster, and Saunders-Roe P531, and three airliners, the Comet 4, the Rotodyne and the Dart Herald.

The flying programme, which starts at 2.30 p.m. on the private days (Tuesday, Wednesday and Thursday) and at 3 p.m. on the public days (Friday, Saturday, Sunday), is expected to open with the Fairey Gannet AEW Mark 3, equipped with air early-warning radar, followed by the English Electric Canberra Mark 11 trainer. Then come the flying test-beds—the Conway-Vulcan, the Tyne-Ambassador (a newcomer), and the Scorpion-Canberra. Nine helicopters then appear—those already mentioned, two Saunders-Roe Skeeters, a Fairey Ultralight, and Westland's Widgeon, Whirlwind and Wessex.

Helicopters are followed by a fly past of airliners and transport aircraft—Viscount 812, Comet 4 and 3B, the Hunting President and the Scottish Aviation Twin Pioneer.

Individual demonstrations follow. An Auster Alpha will demonstrate crop-spraying, followed by an Auster Aiglet trainer, the agricultural D.H. Chipmunk, and the Beaver representing the Canadian side of de Havilland. There will be a demonstration by a Hunting Jet Provost military trainer, and then comes the Dart Herald airliner, the Fairey FD2 supersonic research aircraft, the Rotodyne, the Folland Gnat lightweight fighter, the Gloster Javelin all-weather, and three Hunter aircraft—two fighters and one two-seat version. Finally, the de Havilland Sea Vixen, the Handley Page Victor, the Avro Vulcan Mark 2, the NA39, and the English Electric Lightning will demonstrate the potentialities of tomorrow's first-line military machines.

As last year, Britain's guided missiles will be on display in the static exhibition, and an interesting exhibit by Armstrong Whitworth will be the model of HMS Successful, showing how Sea Slugs are handled aboard a guided weapons ship.

Special Article

A NATIONAL POLICY FOR THE AIRCRAFT INDUSTRY

By Frank Beswick, M.P.

Former Parliamentary Secretary, Ministry of Civil Aviation

Everyone has argued in all the recent discussions and parliamentary debates that Britain needs an aircraft construction industry. Some were concerned with defence requirements; others with the economic contribution which the industry, with its export record and potential, could make. With others it was a direct interest in a business which has yielded a livelihood. And everyone these days, and not only in this country, associates national prestige with success in the air.

But whilst there is this agreement about the end there is nothing like agreement about the means. Some re-organisation and redeployment is clearly inevitable, if only because of the contraction of defence orders. But how should the changes be brought about, and what eventual pattern do we seek? And, above all, what part has the State to play and what should be its position in relation to the industry? If we can decide this latter basic question then many of the other problems will be answered.

Ought the State to come into it at all? Wouldn't competition ensure the survival of the fittest, and couldn't those fit and proven survivors serve our needs at home and secure a fair share of business from abroad? There are reputable and rugged individuals in the industry who have maintained that the State should come into this matter only as a customer. They say they are prepared to quote a price for a specified aeroplane and that the production should be left to them. Though this attitude is in many ways commendable, carried to its logical conclusion it is not realistic. Nor in past experience has this sturdy independence been maintained when a particular company has met with a serious setback on any substantial project. Nor do recent discussions and negotiations connected with the cut-back in military orders suggest that a viable aircraft industry is feasible without active State participation. There are several factors which support this view.

In the first place there is the need for basic aeronautical research. Something like alarm and despondency ran through the industry when with the reduction of defence requirements it was thought that State-financed research would run down. And understandably so. No other nation sustains a significant aircraft industry without national research establishments—certainly this is the case in the United States and the U.S.S.R. The Government's recent policy statement on research and development allayed immediate fears. It did refer to the " expectation that in course of time the industry will progressively assume financial liability for this research " in the civil air transport field where it was not covered by defence research—but further questioning indicated that the Minister had no definite idea as to how this liability could be transferred, nor of any time schedule within which any transfer could be made.

The fact is that the cost of adequate research facilities is beyond the resources of any one company. With, for example, a supersonic wind tunnel costing in the region of £7 million to £10 million it would be absurd not to have a centralised research establishment.

PROTOTYPE COSTS

Moreover there comes a point at which further work in the laboratory or wind-tunnel is fruitless unless designs can be proven in actual flight. And to produce a prototype of a large modern aircraft costs a lot of money. It is true that in the case of the V.C. 10 and the D.H. 121 the firms respectively responsible for these new machines are finding their own finance. But it is also true that both these two new aircraft, though they embody new ideas and though they are confidently expected to take us a sizeable and successful step forward, nevertheless utilise, to a very large extent, the fruits of experience and research fostered by public funds. When we come to consider the next step with large supersonic transport aircraft it seems quite obvious that no private firm can contemplate the unaided expenditure of the money necessary to build a prototype.

The magnitude of the effort needed for aircraft of the future is well illustrated by the case of the so-called Swallow machine. This conception started as a joint Ministry of Supply and private company research study. When the United Kingdom defence requirement for a supersonic bomber was struck out, the M.O.S. withdrew its financial support and Vickers-Armstrongs continued the Swallow study on their own. That was feasible. But now that it has reached the point of embodying one of the designs or some of the ideas into an experimental aircraft it becomes a very different financial proposition. Would it be reasonable for a company to sink the capital, running into many millions, on one prototype which for all its promise may never get to the development, let alone production stage? Almost certainly this imaginative and controversial conception will only get into the air if it is backed by government money, be it British or American.

When a large modern aircraft has passed the prototype stage there still remains an essential and exceedingly expensive proving and development period for both airframe with components, and the power plants. Hitherto, on post-war British machines this proving and development has been carried out to a great extent by the two air corporations. Both B.E.A. and B.O.A.C. have called attention to the cost of the work and there has been some reimbursement from Ministry of Supply funds. One reason why British constructors have emphasised the importance of an initial order from one of the air corporations is because this made it possible to clear a type of aircraft of snags and teething troubles before it went to overseas customers. They are right in insisting that some resources, which they cannot provide, are required for this sector of an aircraft's progress from drawing board to full operation. One suggestion, pressed very strongly both by constructor and operator, is that this responsibility for proving and development should be given to the R.A.F. Transport Command. In the United States a new transport aircraft type is thoroughly flight-tested and proven in a service version by the U.S.A.F. This American arrangement not only has the advantage of solving the financial problem but it also provides a discreet cover for the minor failures which inevitably occur. Not for them the full glare of publicity which accompanies the delay or diversion due to technical troubles of one of Britain's new aircraft in early operational service.

What is the conclusion to be drawn from all the considerations discussed so far? It is surely that if the Services and the publicly-owned corporations are to remain as important and probably the largest customers, if public funds are a pre-requisite for necessary research and development, and if this industry is accepted as an important economic element in the technological Britain of tomorrow, the State cannot contract out of it. The question therefore to be decided is the extent and the character of the State participation.

NOT NATIONALISATION

There are those who would answer this question by nationalisation—the complete and outright ownership of the industry by the State. It is, of course, possible to argue for or against this proposition from a pre-determined political standpoint. I am assuming, however, that we are dealing with this only as a functional or organisational problem. I do not myself believe that nationalisation is the answer. For one thing we are not dealing with an industry in which there are great fixed assets as with the mines, railways, gas or electricity. Of course there are some outer shells of factories and a certain amount of equipment, but the most important element in the aircraft business must be the skills, know-how and design ability and genius of the men who work within it. It is indeed precisely this factor which makes the finished product so valuable as an export.

As opposed to nationalisation the Minister of Supply, in the recent debate, appeared to envisage the very minimum of public initiative and participation. He said then, that even if the State provided adequate basic aeronautical research it would be " fruitless " unless the industry re-organised itself into larger units. Later he declared his belief that this necessary re-organisation, with few but stronger units, would " not come about if the industry is left entirely to itself." But the only power with which he proposed to arm himself in order to make his intervention effective was what he called the " power of the contract." In other words he could take the negative action of withholding a contract if a particular firm had not taken action of which he approved. But he was not himself prepared positively to initiate any course of action. Similarly when making his original announcement of policy, he said it " is recognised that the development of a future generation of aircraft may require a measure of Government support." But this presumably assumes that the decision to start the preliminary work on a future design would be one entirely for a particular firm. One of these may or may not come forward with a project. In the past the service requirement has been the pace-maker; there was no indication in the Minister's statement that any central body would in future be responsible for new specifications for transport aircraft.

NO MINISTER BETWEEN?

But whilst the Minister of Supply did not cast himself in the role of planner-in-chief of the aircraft industry, there are some critics who maintain that progress could best be achieved if he stepped out of the picture altogether. This is usually put in the form that the user, i.e. service departments, ought to deal directly with the maker. Recently this case has been put with much force though with less evidence.

The argument is that the interpolation of a

Continuing A National Policy for the Aircraft Industry

purchasing agency delays decisions, generates undue modifications and generally adds to costs. But the facts suggest that the makers were also critical before the war, and before the M.O.S. was founded, about delays; they always claim that aircraft like the Hurricane and Spitfire were put into production before the user decided to place an order. As for modifications, the evidence before the 1956 Select Committee showed that the majority of modifications arose out of changes in the operational requirements stated by the service department. Moreover the personnel of service departments are very much subjected to postings and promotions. The evolutionary period of a modern project is said to be equal to the tours of duty of three Controllers of Aircraft, for example.

Procurement is, indeed, a specialised operation and informed witnesses to the same Select Committee said it was inconceivable that the duty of ordering equipment should be left " to soldiers, sailors and airmen." Moreover those M.O.S. critics who have considered carefully this service user-maker argument have gone on to advocate the building up of a section within the service department of specially trained individuals. In other words they see the necessity of reproducing the same type, if smaller, organisation under another roof.

The fact is that with modern aircraft, which embody within them such a wide range of industrial effort, and which inevitably entail a period of some years between the drawing board and operational stages, the argument for complete service responsibility over procurement is less strong now than it ever was. If one accepts that, then it must be accepted that we need some State department or other form of public authority with responsibility not only for procurement of service requirements but for the publicly-financed research and for supervision or control of the industry as a whole.

One proposal has been for an organisation for the aircraft industry along the lines of the present Iron and Steel Board. Such a body would consider all investment programmes, collect and disseminate technical and market information and would rely largely on its advisory functions, though with power to make recommendations where necessary for governmental directions or action.

A CENTRAL AUTHORITY

The managing director of the English Electric Company, Mr. H. G. Nelson, has suggested a Central Authority for Civil Aviation. He visualised this body working with the M.O.S. to look after the military side, and ensuring adequate volume of and proper priorities in research and development of civil machines and generally framing a national civil aviation policy.

Either of these two proposals could give British aviation policy, and the aircraft industry, a coherence and a direction which it needs. But both would suffer from inherent defects. If these bodies did not themselves have money to spend then their authority would be very tenuous. If their role was to make recommendations to another Government department which could in turn make finance available then the much criticised indecision and delay would remain. If they did have the necessary funds at their direct disposal there would arise the question of public accountability. How could public funds be provided if there was not responsibility to Parliament? And in any case, even if some formula could be found and the responsibility fastened in some indirect way upon a Minister, how does the Agency or the Board ensure that the monies are spent to the best advantage? It is not easy.

The second report of the Select Committee on Estimates, dealing with the supply of military aircraft, makes the difficulties abundantly clear. The Treasury stated frankly that they had no knowledge of the profits made on contracts awarded by the M.O.S. The M.O.S. were not able to give any idea as to how the profitability of a particular project could be assessed. As one witness put it, " it is extremely difficult to disentangle from the firms' accounts exactly what profits have been made . . . on our work." The Committee itself declared that the system of costing " works capriciously and much too savagely." As to what was produced in return for some public money spent, it was Lord Hives, then chairman of Rolls-Royce, who said " . . . the only thing (some firms) produce is a good balance sheet every year." As for the cost checking of the contracts given to his own firm he said " . . . fellows go round and investigate us (from the Chief Accountant's place). We have had six or eight of these fellows permanently living with us."

The picture that we get of providing public finance from outside and then going in to inspect the work and to check the accounts is one that is both ineffective and expensive. There must be a better way. I would suggest that such a way must involve a more direct and positive participation by the State. Instead of trying to control and check from the outside is there any sound administrative reason why the State should not make its contribution from the inside?

PROPOSED PARTNERSHIP

As I see it this would involve a part-ownership, a share-holding, by the State in selected aircraft firms. With this interest in ownership would go representation on the respective company boards. These directors would be nominated by a Minister who would be responsible for aviation policy as a whole, including air transport and the British air corporations. This Minister could be the Minister of Supply with a reformed and technically strengthened department, or it might well mean the elimination of the old Supply Ministry, in name and with certain functions at any rate, and a new Ministry of Aviation.

The pattern which would emerge if these proposals were adopted would be as follows. There would be a central authority, a Minister answerable to Parliament with general responsibility for the formulation of national aviation policy, and with the means to carry it out. He would be in possession of all information of technical possibilities on the one hand, and on the other, of service requirements and civil market demands. He would be in a position to plan or approve basic research and to ensure that our comparatively limited resources were exploited to the utmost. He could solve the present problem of financing the large projects of the future. The provision of public money to the selected aircraft firms, for research contracts, service orders or civil prototypes, would be made easier for two reasons. In the first place, as the State itself had a financial stake in the firms, it would have a corresponding share in any profits. Secondly, undue profits, fears about " feather-bedding," and the difficulty of " disentangling the accounts," would not arise if the public representatives on the respective boards played their full part in deciding company policy.

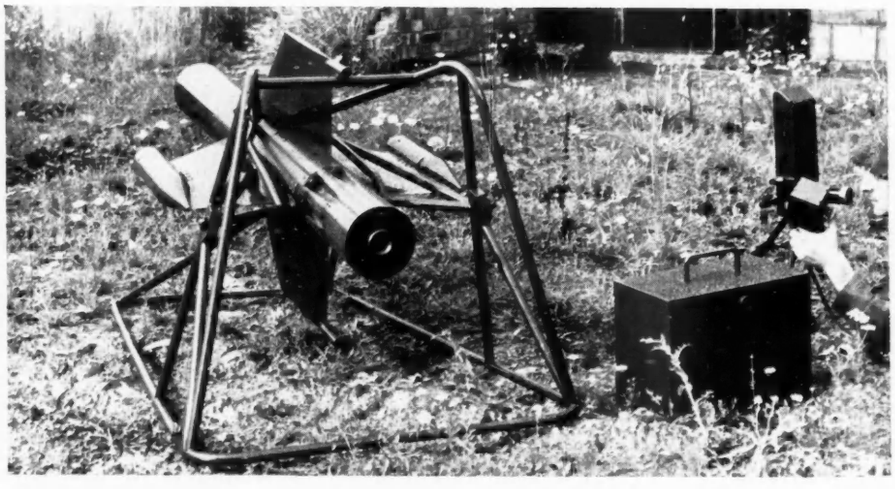
Finally, this kind of partnership between State and industry could help in organisation, policy and finance without cramping the individual initiative in the separate manufacturing firms. Indeed its purpose would be to free the full potential of the proven technical resource and skill within the industry. It would do this by the elimination of over-lapping and the backing of adequate facilities and resources. It is at any rate a solution worth consideration for a problem which must be solved.

SHORT RANGE GUIDED MISSILE

A portable short-range guided missile has been produced by Pye Limited, P.O. Box 49, Cambridge. It can be lifted by one man, is 5 ft long and has a span of 2 ft. The boost and sustainer rockets use solid fuel and the missile is guided to its target by two thin wires that are pulled out of wing tip nacelles. Signals carried by the wires guide the missile on to its target. A simple joystick operated by the controller is used to initiate the guidance signals.

Steering of the missile is not effected by deflecting surfaces but by adjustment of the direction of the rocket efflux. A stabilising gyroscope is contained in the main body of the vehicle. As will be seen from the illustration, the launching equipment is simple and light. If required, the company provide a pair of periscopic binoculars that can be switched rapidly from low to high-power magnification as the missile travels away from the launcher.

The company have not attempted to produce a warhead for the missile as they consider that customers will prefer to produce their own designs according to the particular application they envisage for the missile. In general, however, it is intended for use against armoured vehicles, fortified emplacements, or similar short range targets. The company say that they are satisfied with the test firings and are ready to go into production on receipt of orders from any customer, subject to British Government approval.



The missile trails two thin wires behind it which carry the guiding signals generated by the controller. Steering is by deflection of the rocket efflux.

The Human Element

Limiting the Conflict

The Trades Union Congress have had their hands very full during the past few weeks. They are reported to be at loggerheads with one of the leading members of their General Council, Mr. Frank Cousins, over the bus wage dispute. There is an unsolved problem, again arising from a wage claim, in the gas industry and a great deal to be done in preparation for the annual congress at Brighton early next month.

The T.U.C.'s report on economic policy, published last week, indicated that they are fundamentally opposed to the Government's use of monetary policy as a means of controlling the economy. They call the bank rate "a blunt instrument" and advocate more selective measures, such as "reducing imports, expanding exports, and controlling payments," in order to improve the balance of payments. Greater emphasis should be placed on fiscal policy and direct controls, including credit control. They propose a National Investment Board which could provide information and advice on future trends of investments and advocate measures to stimulate investment, including the control of lending institutions though not of wages.

The report discussed the disagreement with Mr. Cousins during the bus strike. They advised him that to extend the strike with country-wide union support would transform it "from an industrial issue into a much wider conflict with political complications"; and considered that such a clash with the Government "would end in failure which would be disastrous for the whole trade-union investment." There is no evidence that either party to the disagreement has altered its position very much.

Some More Equal

Engineering unions are once again ready to join issue with employers on the vexed question of equal pay for the 190,000 women wage earners in the industry. They are claiming a wage rate for women which would bring them into line with male labourers, and would entail an increase of 24*s.* 6*d.* a week.

The demand was presented to the Engineering and Allied Employers' National Federation last week by Mr. William Carron, president of the Amalgamated Engineering Union. Mr. Carron quoted an article in the treaty establishing the European Common Market which commits member States to the principle of equal pay for equal work. The AEU are likely to argue that if the countries concerned are able to make such an undertaking—four of them, including Germany, are major competitors with Britain in engineering products—so should British engineering employers. The employers are unlikely to reply until they have answered the main claim of engineering unions for an increase of 6 per cent in basic wage rates. The present signs are distinctly unfavourable to an amicable settlement on either claim.

Bond of Steel

The slow-down which has crept over a large section of constructional and manufacturing industry over the past few months is having its impact on the steel industry. Buyers, wherever they can, are reducing stocks and—if American experience is anything to go by—they will not replenish until the prices rise again. A more likely possibility is a cut in motor-vehicle manufacturers' orders for car-body sheet later in the year. Already the steady fall in commercial vehicle sales has affected schedules appreciably.

The two big steel works to go on short time last week are Appleby-Frodingham, a member of the United Steel group, and Workington Iron and Steel Company. Both used to operate five-day weeks. The Appleby-Frodingham company, who already had some 2,600 men on short time, are putting their rolling mill on a four-day week, "because of a further drop in orders for steel plates and sections." This is the second of United Steel's plants to declare short time. Steel, Peech and Tozer have about 2,000 of their 9,000 workers affected. The Workington Iron and Steel Company are experiencing a fall in the demand for rails and fish plates—reflecting the general downturn in railway building activity throughout the western hemisphere. They will go on a four-day week next month.

The absence of any disturbances, despite the anxiety which must prevail among the steel workers, illustrates the excellence of the management-labour relations in the industry. Very few workers have been better treated and the present obvious reluctance of management to lay off workers is evidence of the same spirit of co-operation and understanding of the other side's point of view.

Flattened Spiral

The increase in average weekly earnings in British industry rose in the year up to April, 1958, in exactly the same proportion as basic wage rates—by 4¼ per cent. This is in contrast to the trend in previous years, when earnings rose much more steeply than basic wages. In the past 11 years they have more than doubled (an increase of nearly 107 per cent), while basic rates rose by only 76·4 per cent. This clearly shows the heavy fall in overtime and bonus payments and is only to be expected when industry's rate of expansion almost ceases, as it has done over the period under review.

The Ministry of Labour statistics show that both earnings and wages increased very much less in the six months to April than they had done in the previous six months. Over the twelve months each rose by 4·6 per cent, but between October, 1957, and April, 1958, they each increased by only 0·8 per cent. In April, 1958, an average of £13 1*s.* 3*d.* per week was earned by men in manufacturing industry compared with £12 8*s.* 11*d.* in April, 1957. The corresponding earnings of women amounted to £6 11*s.* 8*d.* and £6 6*s.* 3*d.* respectively. These figures suggest that the Government's efforts to halt wage inflation have been remarkably successful.

Drawing Office Overtime

An article in the August issue of *The Draughtsman*, the journal of the Association of Engineering and Shipbuilding Draughtsmen, argues strongly against overtime working. The author, Mr. Brian G. Richardson, reminds his readers that the AESD have long considered the working of excessive overtime "a menace standing in the way of trade union progress." At the Association's annual conference last year considerable dissatisfaction was recorded on the progress made to oppose "unrestricted and systematic overtime" and the executive committee was instructed to wage "an intensified and vigorous campaign through all levels of the Association" to explain its dangers to members.

Mr. Richardson warns that the AESD is receiving far too little support—"the menace of excessive overtime has failed to receive from many members the very serious attention it deserves." He outlines the campaign which will be waged by the Association and urges members to support it, pointing out that their willingness to put up with it "contradicts trade union policy for a shorter working week." Moreover, he says, overtime tends to have a depressing effect on wage rates, since earnings are constantly quoted as evidence that draughtsmen have no case for asking for more basic pay.

There is little doubt that overtime will be strongly opposed by the AESD and engineering unions at this year's conferences. Most of the arguments will be based on social grounds but basically they will be concerned with wage rates. As Mr. Richardson says in his article, overtime working and other forms of additional earning power "dampen the vigour and militancy required to secure decent basic rates of pay." Many among trade union leaders will agree with him, but will the members of his union?

Safety at Sea

A call for the revision of the International Regulations for the Prevention of Collisions has been made by the Merchant Navy and Airline Officers' Association and by the Mercantile Marine Service Association. These organisations have formed a technical sub-committee to consider suggestions in the light of post-war experience and the increasing availability of marine radar. Senior seagoing members and officials of both organisations, as well as legal advisers, will serve on the committee. The seagoing members will largely be drawn from senior officers serving in ships which are engaged in areas of heavy traffic density, and fitted with radar and other electronic navigational aids.

The associations believe that the questions on the committee's agenda will be considered at the international conference to be held in 1960 for the purpose of revising the 1948 International Convention for the Safety of Life at Sea. That a revision should be necessary so soon is evidence of the immense progress which has taken place in the development of hazard detection equipment, whether obstacles on the sea routes, the proximity of reefs, or hurricanes. It is now possible for ships to be almost completely safe, and the main problem before the two associations and the union is to ensure that safeguards are widely available for all types of shipping, and are properly used in service.

Slaps for Both Sides

The court of inquiry into the dockers' wage demand have severely criticised both sides in the dispute. The dockers, they said, were to blame for not asking for a definite amount: had negotiations been conducted "around a figure rather than a phrase" (the dockers asked for a "substantial" increase) "grounds might have been discovered for agreement or adjustment which would not have been out of line with recent major industrial agreements or awards." The court were even more severe on the employers, and rejected most of their arguments for a wage freeze. There was, they noted, an absence of "any reasoned explanation or exposition of the reasons why any increases of wages that might otherwise appear to be merited could not be absorbed within the industry as a whole and must be wholly passed on to customers in the shipping and other trades." They concluded that an increase of 4·6 per cent —about 7*s.* 6*d.*—a week would be "an appropriate figure for consideration by the parties."

The port employers and dockers' unions are unlikely to reject the court of inquiry's recommendation when they meet on 25 August. The unions are most unlikely to accept anything less than the court have suggested and the majority of employers are thought to be in favour of "making the best of a bad job" and accepting the court's verdict. There is, however, some outspoken criticism of the court's report and some employers are known to favour a trial of strength with the union.

The atmosphere that surrounds the statements on both sides indicates only too plainly that all is not well at the docks.

Plant and Equipment

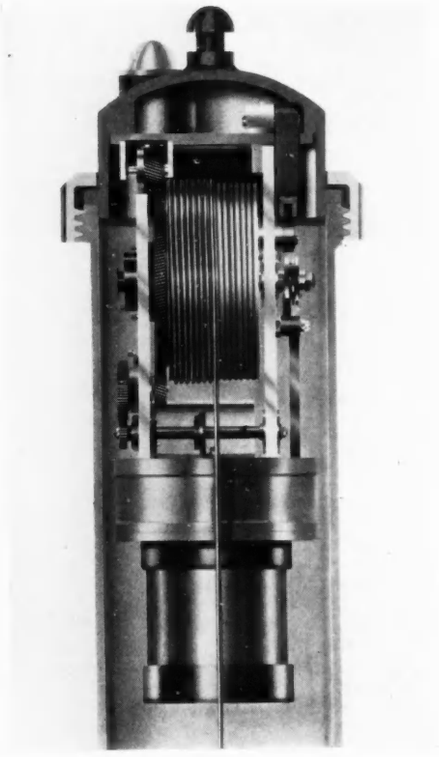


Fig. 7

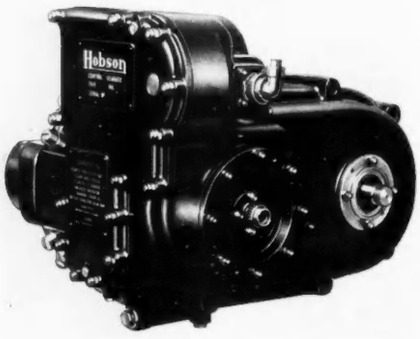


Fig. 8

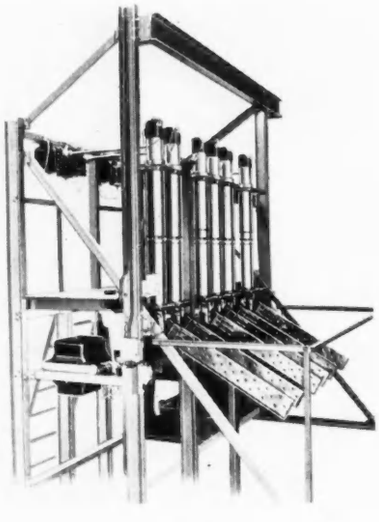


Fig. 9

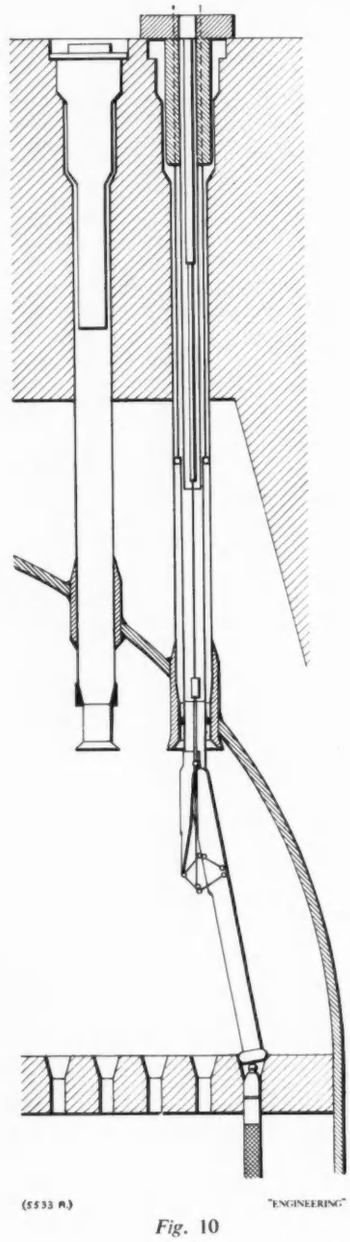


Fig. 10

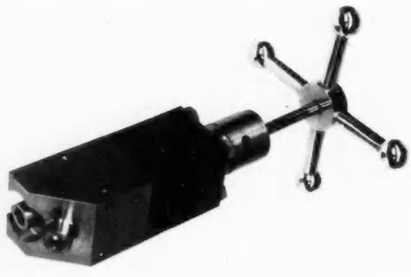


Fig. 11

HARVESTING

Locating the Exhibitors

The addresses and stand numbers of the companies referred to on the following pages are given below.

Aiton and Co. Ltd., Stores Road, Derby. (Stand No. 126.)

British Thomson-Houston Co. Ltd., Rugby, Warwickshire. (Stand No. 103.)

Cambridge Instrument Co. Ltd., 13 Grosvenor Place, London, S.W.1. (Stand No. 115.)

De Havilland Engine Co. Ltd., Leavesden, Nr. Watford, Herfordshire. (Stand No. 127.)

Ekco Electronics Ltd., Ekco Works, Southend-on-Sea, Essex. (Stand No. 116.)

Elliott Bros. (London) Ltd., Century Works, Lewisham, London, S.E.13. (Stand No. 113.)

Etelco. (See Solartron Electronic Group.)

Ferranti Ltd., Holinwood, Lancashire. (Stand No. 125.)

General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2. (Stand No. 124.)

General Radiological Ltd., 15, Clipstone Street, London, W.1. (Stand No. 108.)

Hayward Tyler and Co. Ltd., P.O. Box 2, Luton, Bedfordshire. (Stand No. 134.)

Hispano Suiza Société Anonyme, Rue du Capitaine Guynemer, Bois-Colombes, Seine. (Stand No. 247.)

H. M. Hobson Ltd., Fordhouses, Wolverhampton. (Stand No. 130.)

Isotope Developments Ltd., Aldermaston Wharf, Nr. Reading, Berkshire. (Stand No. 103.)

George Kent Ltd., Biscot Road, Luton, Bedfordshire. (Stand No. 135.)

Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. (Stand No. 103.)

Mullard Equipment Ltd., Mullard House, Torrington Place, London, W.C.1. (Stand No. 111.)

Negretti and Zambra Ltd., 122 Regent Street London, W.1. (Stand No. 107.)

Newman, Hender and Co. Ltd., Woodchester, Stroud, Gloucestershire. (Stand No. 147.)

C. A. Parsons and Co. Ltd., Heaton Works, Newcastle upon Tyne 6. (Stand No. 102.)

Plessey Ltd., Weedon Road, Northampton. (Stand No. 106.)

Pye Ltd., Atomics Division, St. Andrew's Road, Cambridge. (Stand No. 112.)

A. Reyrolle and Co. Ltd., Hebburn, Co. Durham, (Stand No. 102.)

Savage and Parsons Ltd., Watford Bypass, Watford. Hertfordshire. (Stand No. 146.)

Solartron Electronic Group Ltd., Solartron Works, Thames Ditton, Surrey. (Stand No. 110.)

Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex. (Stand No. 119.)

Strachan and Henshaw Ltd., Steelhoist Works, St. Philips, Bristol. (Stand No. 102.)

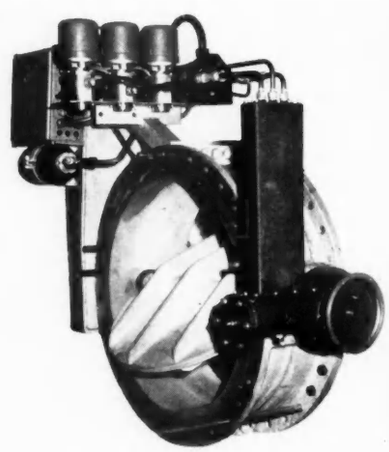


Fig. 12

Fig. 7 *Reactor control-rod winding mechanism designed by the Sperry Gyroscope Company.*

Fig. 8 *Gearbox (type* 350*) for use on reactor control systems made by H. M. Hobson Limited.*

Fig. 9 *Hobson coarse control system for DIDO type reactor installed in test rig.*

Fig. 10 *Fuel-element charge-discharge machine built by the Société Hispano Suiza for the French power reactor EDF.I.*

Fig. 11 *Control and shut-off valve developed by the de Havilland Engine Company for use in radioactive gas circuits.*

Fig. 12 *Butterfly valve made by Hispano Suiza for gas circuits.*

A THREE YEAR NUCLEAR CROP

Atomic Energy Exhibits at Geneva

Continued from page 235

THE growth of a major industry spawns many smaller ones—and many not so small. Since the first International Conference on the Peaceful Uses of Atomic Energy in 1955, the seed of nuclear energy has sprung up in countless fields, and next week at the second conference and at the exhibitions which run concurrently, the three-year harvest will be gathered in. The conference and scientific exhibition are to be held from 1 to 13 September in the Palais des Nations at Geneva, and the industrial exhibition, which lasts for a further day, in the Palais des Expositions. Last week in an introductory article we sought to indicate the changes in thinking in atomic energy matters that might be reflected in the exhibition. The main part of the article was devoted to the exhibits of firms and consortia working on complete power reactors. This week the article continues by describing plant, and instruments for which reactor engineering has created a demand. A final article will consider the apparatus necessary to the further development of nuclear energy through research—experimental instruments, monitors, manipulators, special materials, computers, reactor simulators, accelerators and thermonuclear devices.

Power and Research Reactor Plant

The engineering of nuclear power stations calls for special plant of high quality and reliability, since the escape of coolant or the undetected fracture of a fuel element may be extremely hazardous. Reactor components to be shown at the Atoms for Peace Exhibition are described below.

Control Systems

Apart from instrumentation, the control of nuclear reactors requires a range of sensitive and accurate apparatus, and in particular gear for effecting the insertion and withdrawal of control rods. Equipment of this kind will be exhibited, for example, by the *Metropolitan-Vickers Electrical Company* and the *British Thomson-Houston Company* on the stand of the A.E.I.—John Thompson Nuclear Energy Company. Metropolitan-Vickers built the control systems installed at Calder Hall and Chapel Cross, and B.T.H. are responsible for those to be embodied in the Berkeley nuclear power station.

A control-rod winding mechanism is to be shown by the *Sperry Gyroscope Company*, who will be participating in the group exhibit of the Scientific Instrument Manufacturers' Association. The company's stand will also display other items of control and instrumentation equipment for nuclear power plants. The Sperry winding mechanism, which is illustrated in Fig. 7, will be represented by a full-size display, and incorporates features to ensure safety, reliability and ease of operation and maintenance, for which purpose the entire unit can be removed. The unit, which is fitted with a "gear-tight seal", employs an eddy-current brake, and is driven by a stepping motor, which is shown at the foot of the illustration. A servo-driven control-rod position indicator, also to be seen on the Sperry stand, gives the general position of the control rod, its position to within 0·1 mm, and an indication of the direction and speed of control-rod movement. In addition, there will be examples of the company's d.c. "Vernier" or stepping motors, a large version of which is incorporated in the winding mechanism. These motors are reported to have high torque and digital following characteristics. A range of precision synchros made to international standards will also be shown, together with specialised sensing devices and computers, instrumentation, and electro-hydraulic control systems.

Control equipment for the heavy-water cooled and moderated research reactors DIDO, PLUTO (Atomic Energy Research Establishment, Harwell), DMTR (Dounreay) and HIFAR (Lucas Heights, Australia) has been made by *H. M. Hobson*. It includes a coarse control unit with associated slave gearbox and master gearbox, gearboxes for the fine control and safety-rod systems, and a new gearbox, designated type 350, designed in conjunction with AERE and illustrated in Fig. 8.

Operated through the medium of a coupling shaft from a slave gearbox, the coarse control unit, Fig. 9, comprising a shield plug portion and a cadmium control arm, extends downwards through the reactor top biological shield into the sealed reactor tank. The plug portion provides a pivot at its lower end for the control arm and houses the mechanism which operates the latter in the manner of a signal arm, between the vertical rows of fuel elements. The operating mechanism is designed in two parts which, under operating conditions, are maintained integral by the energising of a magnetic clutch. Following de-energisation, the arm falls by gravity to the maximum "in" or safe position. Limit switches are incorporated to operate warning lights on the control desk at the extreme limits of control-arm movement, the arm moving through some 60° from the horizontal. Six or, alternatively, seven coarse control units, and associated slave gearboxes, are employed in the system. The fine control rod, comprising a cadmium tube, is driven through a Hobson gearbox by a two-phase servo-motor. The safety system, which is duplicated, employs a gearbox and electric motor connected to a drum on which the cable supporting the safety rod is wound; the rod falls under gravity when an electromagnetic clutch is de-energised.

Fuel Element Handling and Inspection

Fuel-element handling gear is an indispensable part of any nuclear reactor, and the British atomic power groups will no doubt be showing examples of typical equipment. In particular, *Strachan and Henshaw Limited* will exhibit on the stand of the Nuclear Power Plant Company an animated fuel-element grab. The use of television for remote observation of the interior of nuclear reactors, particularly in connection with the handling of damaged fuel elements, is becoming established practice. *Pye* Atomics Division will be showing a television camera for a carbon-dioxide cooled reactor with a remotely controlled mirror fitted to the head; this arrangement allows both forward viewing and right-angled inspection of the active area. Alternatively, a manipulator head can be fitted to handle small objects.

A power-operated manipulator, for the continuous remote handling of spent fuel elements from the Calder Hall reactors, has been designed and built by *Savage and Parsons Limited* for the Industrial Branch of the United Kingdom Atomic Energy Authority. After being shown on the company's stand at Geneva, the manipulator will be installed in the new storage pond now being built by the UKAEA at Windscale. The new pond is required to service all the spent fuel elements from both the existing and the new reactors on the adjacent Calder Hall site, and the manipulators are designed specifically to transfer the elements from discharge baskets to skips—a continuous operation while reactor discharge is taking place.

The spent fuel elements, which are 43 in long, over 2 in in diameter and 33 lb in weight, will be loaded into baskets at the discharge points of each reactor and taken to the pond. The manipulators will transfer the 24 elements from each basket, one at a time, and pack them into rail-borne skips which will then be submerged immediately in water for periods up to six months to allow the short-lived activity to decay. Each manipulator can handle up to 30,000 elements a year, the actual operation of transferring the contents of a basket to a skip taking approximately 30 minutes. As they will have come straight from inside the reactors, the fuel elements will be not only highly radioactive but, because of this activity, will also have a temperature of approximately 160° C.

The wall-mounted manipulator is a single vertical telescopic arm with shoulder, elbow and wrist movements, power-operated from a remote control unit. To carry out the transferring operation, the manipulator has been designed with five distinct movements. The complete arm can be raised and lowered a maximum of 15°, pivoting at the mounting position, in a plane at right angles to the wall. It can be extended from 11 ft 9 in overall to a maximum of 18 ft 9 in. The "forearm" can be moved 20° horizontally from the "elbow" in the same plane as the wall. The jaws can be moved vertically from the "wrist"—a maximum of 90°—in a plane at right angles to the wall. Finally, the jaws can be opened and closed. The controls are housed in a box with projecting handlebars, which are operated in conjunction with pedals.

A fuel element charge-discharge machine to be used in the French power reactor EDF1, is to be exhibited by the *Société Hispano Suiza*. The machine, which is illustrated in Fig. 7, has an articulated arm, weighing about 200 kg, equipped with a grab, and is made up basically of two telescopic tubes, a system of joints, and a means of control. The lower tube comprises two jointed sections with flexible guides. By this means it is possible to locate the arm over the charging channel and to control the grab and element as it passes into the tube. The jointing of the two sections is controlled by parallelogram linkages. The movements of the linkages and consequently the motion of the lower section, are remotely controlled by a reduction gear.

Pumps and Valves

The circulation of primary and secondary coolants in nuclear power plants, whether liquid or gaseous, raises a number of important problems; sealing, for example, must be of high-quality. For this reason pumps and valves employed in reactor circulating systems require special standards of manufacture. Blowers and valves for the cooling circuits of large gas-cooled reactors will be shown on the A.E.I.—John Thompson stand by *British Thomson-Houston*.

A sectioned model of a glandless motor pump unit is to be exhibited by *Hayward Tyler and Company*. The unit comprises a single-shaft rotating in two journal bearings within a pressure-tight casing. The upper part of the shaft carries the motor rotor, the pump impeller being at the lower end. The electricity supply cable, entering the casing through sealed stationary glands, is coupled to the plastic-covered stator windings which are immersed in the liquid being pumped. Cooling is effected by a circulating impeller incorporated in the thrust bearing, and by an external heat exchanger. Pumps of this type are employed in the primary and secondary

Continuing Harvesting A Three Year Nuclear Crop

circulation systems of nuclear reactors. Also on display is an illuminated diagram illustrating the operation of the steam generating system in a nuclear power station.

Among the pumps to be shown by *Hispano Suiza* will be the type 552144. It is a piston pump for heavy water with an output pressure of 100 kg per sq. cm and an operating temperature of up to 200° C; the pumping speed is 20 litres per minute. A solenoid valve for heavy water will also be displayed. Operating at 350 kg per sq. cm it is tested to 525 kg per sq. cm. An operating voltage of 24 or 48 V is required.

Pumps and valves for high-temperature gas-coolant circuits have been developed by the *de Havilland Engine Company*, who will show design details of small high-speed gas circulators incorporating self-acting gas bearings. A full-size model of a circulator will also be exhibited, together with an electrically-energised rotative assembly mounted on self-acting gas journal bearings to demonstrate their action. These items are under development for the HTGC loop referred to last week. The components of control and shut-off valves for use in radio-active gas circuits will also be on show. In the control and shut-off valve illustrated in Fig. 11, external leakage is said to have been eliminated by the use of a welded-in bellows assembly. To safeguard against failure of these bellows a secondary seal using O-rings has also been incorporated. All other external joints in the valve body are welded.

The butterfly valve shown in Fig. 12, which has been designed for gas circuits, will be exhibited by *Hispano Suiza*. It will be equipped with a hydraulic control system and can be operated by visitors by pushing appropriate buttons. The interior of the control mechanism will be displayed schematically alongside. The valve gives rapid rates of control of gas flow, and a feature of its design is the system of sealing. Coatings of nickel or chromium cover the larger surfaces, to protect them against corrosion. It is possible to control the valve in various ways: electric motor, pneumatic jack, hydraulic jack, hydraulic motor, and by other means. The illustration shows the valve coupled to a hydraulic servo-system. A gas compressor rotor will be displayed as an example of the company's design in this field, together with various pumps and actuators.

A selection of valves specially designed for use in atomic energy installations will be displayed by *Newman, Hender and Company*. The range exhibited will include forged-steel globe and gate valves, needle-type bellows-sealed valves, and parallel slide valves with seal-weld flanges.

Power Station Plant

Plant for nuclear power stations includes a wide range of conventional equipment. Thus on the stand of the Nuclear Power Plant Company, *Head, Wrightson and Company* will be showing a model of a "Counterflo" induced-draught cooling tower; and a model of a typical feeder circuit of a 132 kV duplicate busbar switching station similar to those being installed at Bradwell will be exhibited by *A. Reyrolle and Company*, who will also be showing a full-size sectional model of a 275 kV air-blast circuit-breaker head. Steam turbines, on the other hand, have to be designed to use the comparatively low-quality steam at present available from reactor plants, and Fig. 13 illustrates a model of a 100 MW turbo-alternator designed specifically for installation in nuclear power stations by *C. A. Parsons and Company*.

Aiton and Company are displaying a full-size heating unit and ebullition chamber to represent the complete Aiton "Alkacide" plant and evaporator for purifying sea water or estuary water for nuclear power stations. The efficiency of the Aiton Mark 2 "Uniload" support will be demonstrated by means of a standard load-deflection test utilising a 3 ton spring balance in series with a hydraulic pulling ram. The vertical travel of this support will be at least 6 in (152 mm) and it will be shown that the load deflection graph does not depart from the ideal straight line by more than plus or minus 1 per cent. The company will also be exhibiting expansion fittings, corrugated pipework, pipework for advanced service conditions, and models of these and other items.

Fig. 13 (below) Model of a 100 MW turbo-alternator designed specifically for nuclear power stations by C. A. Parsons and Company.

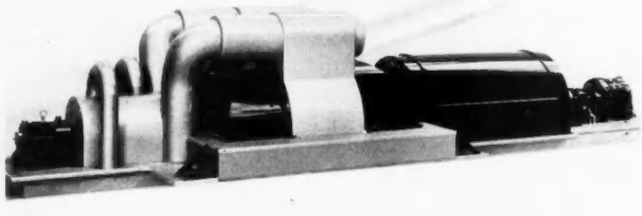
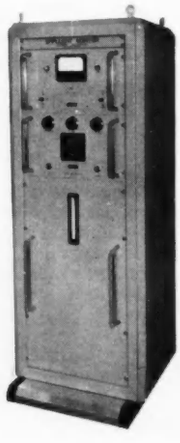


Fig. 14 (right) Reactor effluent monitor made by Plessey Nucleonics.



Reactor Instrumentation

Instrumentation in nuclear power stations may be divided into two categories: that recording normal operation, and that for detecting faults. Prominent among the second group are the instruments designed for detecting burst fuel cartridges. In the next article reference will be made to computers and reactor simulators employed in the design of nuclear reactors.

Monitoring and Fault Detection

Departure from normal reactor operation may be signalled by an undue increase in neutron flux, or contamination of the coolant stream due to a burst fuel slug. Monitoring must also be employed to ensure that effluent from a reactor is not so radioactive as to cause a hazard to staff or to the general public.

An animated diagram will be displayed by the *General Electric Company* to demonstrate the elaborate monitoring system, incorporated in nuclear reactor designs, for the rapid detection of faults developing in fuel-element cans. Gas samples are automatically taken every 40 minutes from each of the 3,288 fuel channels in the reactor, and their fission-product content measured and recorded. Any failure can be readily located and the faulty element removed before radioactivity of the gas-stream reaches a dangerous level.

Various control and monitoring systems will comprise the main body of exhibits on the stand of *Plessey Nucleonics*, which will include a reactor effluent monitor (Fig. 14) as an example of installed health instrumentation. Ionisation chambers and fission counters will also be displayed. Particular emphasis will be laid on B.S.D. (burst-slug detection or faulty fuel element location) installations for both gas and water-cooled reactors. A flux scanning system employing an ionisation chamber is also to be displayed. This equipment is intended to provide a rapid measurement of the neutron flux distribution within the core of a large gas-cooled reactor. A small neutron-sensitive ionisation chamber is used to measure flux. The chamber is lowered through the core of the reactor on the end of a temperature-resistant flexible cable from a winding head which is installed in a stand-pipe on the pile cap, the output of the chamber being passed by way of the winding head to a chart recorder. A number of winding heads are installed across the pile cap, each head being operated in turn from a control panel.

Sunvic Controls and *Isotope Developments* will exhibit on the A.E.I.—John Thompson stand examples of nuclear instrumentation including a memory drum, a Barton meter, a level detector, and an auto-scaler. The magnetic memory storage drums are for use in the burst-fuel cartridge computer being built by Sunvic for the Berkeley nuclear power station. The drum, which will be complete with recording heads, has a capacity of approximately 500,000 binary digits. At Berkeley each drum will memorise the previous forty-eight counts from each of more than 400 channel groups. There will be two exhibits showing the flexibility of the Sunvic high-impedance single-point and new multi-trace potentiometric recorders. These will demonstrate some of the standard additional facilities available such as high and low-level alarm indication, retransmitting slide-wire and decimal print-out.

A new system of reactor safety equipment that is said to offer greater reliability than systems currently in use has been developed by *Mullard Equipment Limited*. The system, which embodies the principle of failure to safety required for nuclear power reactors, will be shown for the first time at Geneva. Equipment of this kind constructed to the requirements of the UKAEA will shortly be installed at the Dounreay atomic power station, where it will undergo field trials. The enhanced reliability of the new system is due to the replacement of conventional electro-mechanical relays by transistor logic circuits to perform the necessary switching operations, and to the use of printed circuitry and advanced assembly methods. The extensive employment of transistors also reduces the power requirements of the system by a significant amount. The function of the system is to initiate warning or shut-down conditions in the reactor plant when fault signals are received from instruments monitoring the significant parameters of the pile. To prevent a spurious shut-down the system also determines when a fault signal is due to the failure of a monitoring channel and not to a reactor abnormality.

The monitoring channels may be of two types: "action" channels, set to trip when the parameter they measure reaches its maximum permissible excursion, requiring the reactor to be shut-down; and "warning" channels, indicating abnormal parameter values not necessarily requiring a shut-down, or giving an early indication that shut-down conditions may develop. During normal operation the monitoring channels feed a steady signal into the safety system which ceases when an abnormality occurs. To ensure complete safeguarding, the "action" channels are grouped in threes, each group providing three independent measurements of the same parameter. The safety system accepts the inputs from each group on a two-from-three basis; that is to say, the logic units are so combined that a shut-down is initiated only if fault signals are received from at least two of the channels in a particular group. Thus a shut-down is ensured if a parameter becomes abnormal, or if two or all

three channels indicate "action" due to the channels themselves failing. If only a single channel fails shut-down does not occur.

Control Instrumentation

Ranges of separate instruments and complete instrument panels will be shown by a number of exhibitors. Thus *Ekco Electronics* will display a reactor control panel, incorporating typical instruments from the company's range. The panel represents part of the control room of a heavy-water moderated research reactor such as PLUTO, DMTR, HIFAR in Australia and DR3 in Denmark. The instruments shown include three new transistorised units designed to minimise maintenance problems. On the combined stand of *Solartron* and *Etelco* will be shown a LIDO reactor control rack built by Etelco for AERE.

A display panel to be shown by *Elliott Brothers (London) Limited* is of graphic form and is illustrated in Fig. 15, where the sections devoted to the reactor and the heat exchangers can be seen. Some of the instruments fitted in the control panel are as follow. A 54-point scanning recorder type ND.52, records the outputs from burst fuel-element equipment. Each output is displayed separately on a special chart so that the trend of each can be readily observed. (Recorders of this type are in use at Calder Hall). A Dynamaster recorder indicates the position of a selected group of control rods. For this purpose the normal recorder slide wire is replaced with a magslip coincidence motor receiving a signal from a transmitter mounted with the control-rod drive. A neutron-flux recorder registers the output from a linear amplifier measuring neutron flux level in the reactor. Various Swarthout instruments record pressure and temperature differentials, while Dynamometer recorders give readings of coolant-gas flow rate and heat output. Panellit annunciators indicate reactor shut-down and alarm conditions, and also alarm conditions for temperature, pressure, flow and level.

Another part of the Elliott display will comprise racks containing a variety of reactor control instrumentation, including ionisation chambers for health monitoring, reactor power meters, flux meters and fine-control and shut-down amplifiers.

General Radiological Limited will be displaying a complete control cubicle of the kind they are making for the Bradwell nuclear power station, now under construction by the Nuclear Power Plant Company. This cubicle, which has been designed with particular attention to ventilation, safety and accessibility, will be fully instrumented and will demonstrate not only the complete range of reactor instruments made by the company, but also their competence to undertake complete schemes. Among the items on display will be the following: complete neutron counter withdrawal mechanism as used during reactor start up; neutron sensitive ion chambers; foil counting equipment for flux scanning; annular ion chambers for flux plotting; installed neutron monitors; alpha, beta and gamma monitors; transistorised scalers; and control potentiometers, one of which is shown in Fig. 16.

A control-rod speed recorder will be among the instruments to be shown by the *Cambridge Instrument Company*. It is designed for testing the emergency shut-down arrangements of a nuclear reactor, and records on a chart the dynamic characteristics of a falling rod, including the instant of release and the end of the fall. The test cycle is entirely automatic, being operated by one pressure of a button; on completion of the cycle the recorder resets itself and switches off the chart drive. Other control instruments to be on display include a model DE electronic recorder-controller; an indicator and alarm outfit for checking the purity of carbon dioxide used as a heat-transfer medium; and a "Centre-Line" controller. In this instrument a portion of the scale is projected optically on a translucent illuminated screen, providing an effective length of 20 in; the scale is adjusted to bring the desired value in line with a fixed datum on the centre line of the instrument, and the plant is on control when the galvanometer pointer, which is projected on the same screen, is coincident with the datum.

The main item of interest on the stand of *George Kent* will be the Multelec Mark 3 high-speed electronic strip-chart recorder, available for such applications as temperature, millivoltage, reactor power-level measurement (both linear and logarithmic); reactor power-drift measurement; gamma health monitoring; gamma activity in fluid circuits; control arm or rod position and analogue-computers. A particularly interesting version of the instrument is a multi-point scanner with a new presentation system. It will be shown recording the readings from 90 separately scanned points on a single chart, with clear identification of each reading.

Kent will also be showing the Kent-Barton non-mercurial meter in their Commander range for flow, level, specific gravity and other measurements where wet gas, corrosive fluid or level-mounting difficulties are involved; their new synchronous converter; standard Kent electronic units—amplifiers, reference-current source and servo-motors—demonstrated in the form of a servo-system maintaining at constant-level the light falling on a photo-cell; and a Dall tube and a Dall orifice giving a high degree of pressure recovery during flow measurement.

Negretti and Zambra, who are development contract engineers for the UKAEA, have contributed to the SIMA stand from their range of measuring and control instruments, specially developed for atomic energy applications. Instruments have been made for atomic plants at Dounreay, Calder Hall, Aldermaston, Harwell, Chapel Cross and Saclay (France). Negretti and Zambra instruments for atomic energy applications include the two following. Pressure amplifiers are used to give remote readings of small pressure fluctuations; their use enables the recording and control of several parts of a plant to be concentrated at a single point. The Negretti gap measuring probe is for measuring gap widths by means of a transmitting capsule built up from diaphragms of the company's manufacture. The probe is particularly useful in those conditions where the gap to be measured is in such a position as to exclude the more conventional methods of measurement.

A new multi-point thermocouple temperature recorder, which provides a permanent printed record of the temperature being measured from any one of up to 500 points, the time at which it was taken and the channel identification, is being produced by *Savage and Parsons*, and a pre-production model will be shown on their stand. The recorder consists, basically, of two units. One contains a precision voltage supply for the thermocouples, and the printing head, motor-driven slidewire and servo equipment; and the other unit is an extension box housing 50 thermocouple connections, selector switching and provision for a cold-junction oven. Additional extension boxes—each with 50 thermocouples—can be added, as required, to give up to 500 points. The maximum temperature range of the equipment is 800° C to 1,000° C, depending on the type of thermocouple used. The measurements are recorded on a 3 in wide strip chart, capable of accommodating a total of 3,000 readings on its 50 ft length. The maximum rate of printing is approximately 100 measurements a minute, each measurement comprising the three variables: time, temperature and channel. The equipment will be shown attached to a small model of a reactor core, as one of the expected uses is the continuous reading of reactor-core temperatures.

Detailed reference to reactor simulators will be made next week, but Fig. 17 shows a simulator made by *Elliott Brothers* for instructional purposes.

(To be continued)

Fig. 15 (left) Display panel built by Elliott Brothers (London) Limited for use in a nuclear power plant, showing the areas devoted to the reactor and heat exchangers.

Fig. 16 (right) Control potentiometer made by General Radiological Limited.

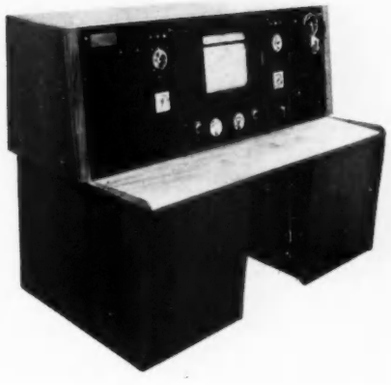


Fig. 17 (right) Reactor simulator designed and built by Elliott Brothers for instructional purposes.

EXHIBITIONS AND CONFERENCES

This list, in chronological order, appears in the last issue of each month. Events noticed for the first time and alterations of dates, places, etc., are indicated by an asterisk (*). For details of events not included below, reference should be made to ENGINEERING, 27 *June, page* 831, *and* 25 *July, page* 125. *Organisers are invited to send particulars of coming events to the Editor.*

Salinity Problems in Arid Zones, Symposium.—In September, at The University, Teheran, Iran. Organised jointly by UNESCO and the Iranian Government. Apply to the Natural Sciences Department, UNESCO, 19 Avenue Kléber, Paris 16e.

Farnborough Flying Display and Exhibition.—Mon., 1 Sept., to Sun., 7 Sept., at Farnborough, Hampshire. Open to the public on Fri., Sat. and Sun., 5, 6 and 7 Sept., only. Organised by the Society of British Aircraft Constructors Ltd., 29 King Street, London, S.W.1. Tel. TRAfalgar 3231.

Analogy Computation Meeting, Second International.—Mon., 1 Sept., to Tues., 9 Sept., at Strasbourg, France. Apply to Mr. F. H. Raymond, Association Internationale pour le Calcul Analogique, 138 Boulevard de Verdun, Courbevoire, Seine, France.

Peaceful Uses of Atomic Energy, Second International Conference.—Mon., 1 Sept: to Sat., 13 Sept., at Geneva, Secretariat, 1 Place du Lac, Geneva, Switzerland. Apply to the secretary, the executive committee, 1958 Geneva Conference, Atomic Energy Research Establishment, Harwell, Berks. See ENGINEERING, 16 August, 1957, page 218.

Pan American Federation of Engineering Societies, 5th Convention.—Tues., 2 Sept., to Sat., 6 Sept., at Montreal, Canada. Organised by the Engineers Joint Council, 29 West 39th Street, New York 18.

***Utrecht International Autumn Fair.**—Tues., 2 Sept., to Thur., 11 Sept., at Utrecht, Holland. Apply to Mr. W. Friedhoff, Netherlands Chamber of Commerce, 10 Gloucester Place, London, W.1. Tel. WELbeck 9971.

Domestic Equipment Trades Fair.—Tues., 2 Sept., to Thurs., 11 Sept., at Olympia, London, W.14. Organised by B. C. and D. Trade Exhibitions Ltd., 194-200 Bishopsgate, London, E.C.2. Tel. AVEnue 1444.

Cybernetics, Second International Conference on.—Wed., 3 Sept., to Wed., 10 Sept., at Namur. Organised by the International Association for Cybernetics, 13 Rue Basse-Marcelle, Namur, Belgium.

DO IT YOURSELF

Handicrafts and Do It Yourself Exhibition, Sixth International.—Thurs., 4 Sept., to Fri., 19 Sept., at Olympia, London, W.14. Exhibition offices: 24 Store Street, London, W.C.1. Tel. MUSeum 9792.

Cologne Fair (Household Goods and Hardware).—Fri., 5 Sept., to Mon., 8 Sept., in Cologne. *Agent:* Mr. M. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

Aslib Annual Conference.—Fri., 5 Sept., to Mon., 8 Sept., at The University, Nottingham. Organised by Aslib, 3 Belgrave Square, London, S.W.1. Tel. BELgravia 5050.

Brazilian State Agricultural Exhibition.—Sat., 6 Sept., to Tues., 9 Sept., at Porto Alegre. Organised by the Secretariat of Agriculture, Porto Alegre, Brazil.

World Power Conference, Sectional Meeting.—Sun., 7 Sept., to Thurs., 11 Sept., at the Queen Elizabeth Hotel, Montreal. Apply to the secretary, British National Committee, World Power Conference, 201-202 Grand Buildings, Trafalgar Square, London, W.C.2. Tel. WHItehall 3966. *Note:* A Sectional Meeting of the conference will be held in Madrid in 1960; the Sixth Plenary Meeting in Australia in 1962; and a Sectional Meeting in Switzerland in 1964.

American Chemical Society.—Sun., 7 Sept., to Fri., 12 Sept., at Chicago, Ill., U.S.A. Organised by the Society, 1155 Sixteenth Street, Washington 6, D.C., U.S.A.

Leipzig International Autumn Fair.—Sun., 7 Sept., to Sun., 14 Sept., at Leipzig. *Agents:* Leipzig Fair Agency, 127 Oxford Street, London, W.1. Tel. GERrard 0357.

Aeronautical Sciences, First International Congress on.—Mon., 8 Sept., to Sat., 13 Sept., in the Instituto Nacional de Prevision, Alfonso XI, Madrid. Further information from the Royal Aeronautical Society, 4 Hamilton Place, London, W.1. Tel. GROsvenor 3515.

Ions of the Transition Elements, Discussion on.—Tues., 9 Sept., to Thurs., 11 Sept., in Dublin. Organised by the Faraday Society, 6 Gray's Inn Square, London, W.C.1. Tel. CHAncery 8101.

Place of the University in the Education of Civil Engineers, Conference.—Tues., 9 Sept., to Fri., 12 Sept., at the Queen's University of Belfast. Open to civil engineering delegates from industry and the universities. Apply to the organising secretary, David Keir Building, Stranmillis Road, Belfast.

Chemical Exposition, National.—Tues., 9 Sept., to Fri., 12 Sept., at the International Amphitheater, Chicago. Organised by the Chicago Section, American Chemical Society. Offices of the Society: 86 East Randolph Street, Chicago, Ill., U.S.A.

European Organisation for Quality Control.—Wed., 10 Sept., to Fri., 12 Sept., in Essen, Western Germany. Theme: "Consumer-Vendor Relations." Organisation's offices: Koninginnegracht 101, The Hague, Holland.

Coal Petrology, First International Meeting on.—Wed., 10 Sept., to Sat., 13 Sept., at Heerlen, Holland. Organised by the Committee on Coal Petrology, Geoligsch Bureau, Akerstraat 86-88, Heerlen, Holland.

Bulawayo Agricultural Show.—Wed., 10 Sept., to Sat., 13 Sept., at Bulawayo. Organised by the Bulawayo Agricultural Society, Bulawayo, Rhodesia.

International Scientific Film Association; 13th Congress.—Wed., 10 Sept., to Sat., 20 Sept., in Moscow. Apply to the Scientific Film Association, 164 Shaftesbury Avenue, London, W.C.2. Tel. TEMple Bar 4694.

Shipping and Commercial Fishing Exhibition.—Thurs., 11 Sept., to Wed., 17 Sept., in Hull. Organised by Anglo-European Exhibitions Ltd., 45 Park Lane, London, W.1.

Conservation of Nature and Natural Resources, International Union for.—Thurs., 11 Sept., to Fri., 19 Sept., at Athens and Delphi, Greece. Sixth general assembly and seventh technical meeting. Union address: 31 Rue Vautier, Brussels, Belgium.

SWISS COMPTOIR

Swiss National Autumn Fair (Swiss Comptoir).—Sat., 13 Sept., to Sun., 28 Sept., in Lausanne. Fair offices; Palais de Beaulieu, Lausanne, Switzerland.

Kekulé Symposium on Theoretical Organic Chemistry.—Mon., 15 Sept., to Wed., 17 Sept., in London. Arranged by the Chemical Society under the auspices of the Section of Organic Chemistry of the International Union of Pure and Applied Chemistry. Offices of the Society: Burlington House, Piccadilly, London, W.1. Tel. REGent 0675.

Instrument Automation Conference and Exhibit, 13th Annual.—Mon., 15 Sept., to Fri., 19 Sept., in the Convention Hall, Philadelphia. Organised by the Instrument Society of America, 3443 South Hill Street, Los Angeles 17, Cal., U.S.A. Apply to Export and Publicity Fairs Branch, Board of Trade, Lacon House, Theobald's Road, London, W.C.1. Tel. CHAncery 4411.

Large Dams, International Commission on, World Power Conference.—Mon., 15 Sept., to Sat., 20 Sept., in New York. Communications to the secretary, British National Committee on Large Dams, 201-202 Grand Buildings, Trafalgar Square, London, W.C.2. Tel. WHItehall 3966.

***Marine and Power Engineers, 16th International Meeting.**—Mon., 15 Sept., to Sat., 27 Sept., at Wrightsville, near Wilmington, North Carolina, U.S.A. To discuss corrosion problems and for inspection of corrosion testing stations at Kure Beach and Harbor Island. Organised by the International Nickel Co., Inc. Apply to Mr. F. Hudson, Development and Research Department, Mond Nickel Co., Ltd., Millbank, London, S.W.1. Tel. VICtoria 3888.

***Leadership, Conference on.**—Tues., 16 Sept., at Connaught Rooms, London, W.C.2. Organised by the British Institute of Management, 80 Fetter Lane, London, E.C.4. Tel. HOLborn 3456.

Association of Public Lighting Engineers, Annual Conference.—Tues., 16 Sept., to Fri., 19 Sept., at the Royal Hall, Harrogate. Includes an exhibition of street-lighting equipment and an outdoor display of lamp columns and mobile equipment. Organised by the Association of Public Lighting Engineers, 76 Victoria Street, London, S.W.1. Tel. VICtoria 3655.

***Gas Discharges, Conference on.**—Wed., 17 Sept., to Sat., 20 Sept., at the University College, Swansea. Organised by the Physical Society, 1 Lowther Gardens, South Kensington, London, S.W.7. Tel. KENsington 0048.

Melbourne, Royal Agricultural Show.—Thurs., 18 Sept., to Sat., 27 Sept., at Melbourne. Organised by the Royal Agricultural Society of Victoria, 422 Collins Street, Melbourne, Australia.

American Institute of Chemical Engineers, National Meeting.—Sun., 21 Sept., to Wed., 24 Sept., in Salt Lake City. Apply to the Institute's Greater Salt Lake City Section, P.O. Box 1889, Salt Lake City, Utah, U.S.A.

Gas Congress, Seventh International.—Mon., 22 Sept., to Thurs., 25 Sept., in Rome. Organised by the International Gas Union, 4 Avenue Palmerston, Brussels 4, Belgium.

Heating, Ventilation and Climate Effects on the Human Body, International Congress on.—Mon., 22 Sept., to Fri., 26 Sept., in Brussels. Apply to the congress secretary, Mr. H. A. Roba, 163 Rue Royale, Brussels, Belgium.

Business Efficiency Exhibition.—Mon., 22 Sept., to Sat., 27 Sept., at the City Hall, Manchester. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate Hill, London, E.C.4. Tel. CENtral 7771.

Institute of Metals Autumn Meeting.—Mon., 22 Sept., to Sat., 27 Sept., in Birmingham. Offices of the Institute: 17 Belgrave Square, Westminster, London, S.W.1. Tel. BELgravia 3291.

Future of Non-Ferrous Mining in Great Britain and Ireland, Symposium.—Tues. and Wed., 23 and 24 Sept., at 21 Tothill Street, London, S.W.1. Organised by the Institution of Mining and Metallurgy, 44 Portland Place, London, W.1. Tel. LANgham 3802.

Gearing, International Conference.—Tues., 23 Sept., to Thurs., 25 Sept., in London. Organised by the Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, S.W.1. Tel. WHItehall 7476. See ENGINEERING, 11 July, p. 36.

***Cosmic Rays, Conference on.**—Wed. and Thurs., 24 and 25 Sept., at the Durham Colleges, The University, Durham. Organised by the Physical Society, 1 Lowther Gardens, South Kensington, London, S.W.7. Tel. KENsington 0048.

***Art of Selling, Course on.**—Wed. and Thurs., 24 and 25 Sept., at Grosvenor House, Park Lane, London, W.1. Two-day course by Mr. Heinz M. Goldmann. Organised by the British Institute of Management, 80 Fetter Lane, London, E.C.4. Tel. HOLborn 3456.

Industrial Fuel Efficiency Exhibition.—Wed., 24 Sept., to Fri., 3 Oct., at Olympia, London, W.14. Organised, in association with F. W. Bridges and Sons, Ltd., by Provincial Exhibitions Ltd., City Hall, Deansgate, Manchester 3. Tel. Deansgate 6363.

Scientific Unions, International Council of Eighth General Assembly.—Thurs., 25 Sept., to Sun., 5 Oct., at Washington, D.C., U.S.A. Apply to Dr. A. Atwood, National Research Council, National Academy of Sciences, Washington, D.C., or to the International Council of Scientific Unions, 29 Tavistock Square, London, W.C.1.

Commercial Motor Transport Exhibition, International.—Fri., 26 Sept., to Sat., 4 Oct., at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders Ltd., 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

"Photokina" International Photographic and Cinematographic Exhibition.—Sat., 27 Sept., to Sun., 5 Oct., in Cologne. *Agent:* Mr. M. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

Electrochemical Society Inc., Conference.—Sun., 28 Sept., to Thurs., 2 Oct., at Ottawa. Offices of the Society: 216 West 102nd Street, New York 25.

Independent Hardware Exhibit, Third Annual.—Sun., 28 Sept., to Fri., 3 Oct., at the Barbizon Plaza Hotel, New York. Organised by the Independent Hardware Exhibit, Inc., 299 Madison Avenue, New York 17, U.S.A.

Watch and Jewellery Trade Fair, Fourth International.—Mon., 29 Sept., to Fri., 3 Oct., at the Royal Albert Hall, London, S.W.7. Organised by Trade Fairs and Promotions, Ltd., Drury House, Russell Street, London, W.C.2. Tel.: TEMple Bar 3422.

***Industrial Safety Week, National.**—Mon., 29 Sept., to Sat., 4 Oct. Organised by the Royal Society for the Prevention of Accidents, 75 Victoria Street, London, S.W.1. Tel. ABBey 6963.

Civil Engineering in Agriculture, Fifth Congress.—Mon., 29 Sept., to Sat., 4 Oct., in Brussels. Apply to the Agricultural Attaché, Belgian Embassy, 105 Eaton Square, London, S.W.1.

RAILWAY CONGRESS

International Railway Congress Association's 17th Congress.—Mon., 29 Sept. to Tues., 7 Oct., at Madrid. Organised by the Permanent Commission, 19 Rue du Beau-Site, Brussels, Belgium.

European Management Conference.—Tues., 30 Sept., to Fri., 3 Oct., in the Kongresshalle, Berlin. Apply to the British Institute of Management, 80 Fetter Lane, London, E.C.4. Tel. HOLborn 3456.

Chemical Engineering Exhibition ("KJEMI-TEKNIKK 58").—In October at Oslo. Organised by the Studieselskapet for Norsk Industri, Forskningsveien 1, Blindern/Oslo, Norway.

***Motor and Cycle Show, 45th International.**—Thurs., 2 Oct., to Sun., 12 Oct., in Paris. *Agent:* Mr. R. C. Liebman, 178 Fleet Street, London, E.C.4. Tel. CITy 5889.

***National Electronics Conference.**—Mon., 13 Oct., to Wed., 15 Oct., at the Hotel Sherman, Chicago, Ill., U.S.A. Sponsored by the American Institute of Electrical Engineers, Illinois Institute of Technology, the Institute of Radio Engineers, and the Illinois Northwestern Universities. Offices: 84 E. Randolph Street, Chicago 1, Ill., U.S.A.

***Chemical Engineering Exhibition, International.**—Thurs., 16 Oct., to Sun., 26 Oct., in Oslo. Apply to Studieselskapet for Norsk Industri, Forskningsveien 1, Blindern, Oslo, Norway.

***Hotel and Catering Industry Exhibition, Fifth International.**—Sat., 18 Oct., to Wed., 29 Oct., in Paris. Exhibition offices: 13 Rue de Liège, Paris.

***Tunis Trade Fair, Sixth International.**—Sat., 18 Oct., to Sun., 2 Nov., in Tunis. Organised by the Foire Internationale de Tunis, Palais Consulaire, Avenue Roustan, Tunis.

***Directors' and Executives' Exhibition.**—Mon., 20 Oct., to Fri., 24 Oct., at the Royal Horticultural Society's Old Hall, Vincent Square, London, S.W.1. Organised by Specialised Exhibitions Ltd., 58 Jermyn Street, London, S.W.1. Tel. HYDe Park 1391.

***Recent Developments in Precast Concrete, Symposium.**—Tues., 21 Oct., at the Building Centre, 26 Store Street, London, W.C.1. Apply to Concrete Ltd., 16 Northumberland Avenue, London, W.C.2. Tel. WHItehall 5504. (Alteration of date.)

Canadian National Packaging Exposition, Seventh.—Tues., 4 Nov., to Thurs., 6 Nov., in the grounds of the Automotive Building, Toronto. Organised by the Packaging Association of Canada, 1 St. Clair Avenue West, Toronto 7, Canada.

***Bottling Exhibition, 12th International.**—Tues., 4 Nov., to Thurs., 13 Nov., in Paris. Exhibition offices: 28 Rue Louis-le-Grand, Paris, 9e.

***Mechanical Handling Exhibition, International.**—Wed., 5 Nov., to Thurs., 13 Nov., in Paris. Apply to the Salon de la Manutention, 40 Rue du Colisée, Paris, 8e.

***Packing and Distributing Exhibit 11th International.**—Wed., 5 Nov., to Thurs., 13 Nov., in Paris. Exhibition Offices: 40 Rue du Colisée, Paris, 8e.

***Motor Show, 40th International.**—Wed., 5 Nov., to Sun., 16 Nov., in Turin. Offices: Corso Galileo Ferraris 16, Turin, Italy.

PUBLIC WORKS

Public Works and Municipal Services Congress and Exhibition.—Mon., 10 Nov., to Sat., 15 Nov., at Olympia, London, W.14. Organised by the Municipal Agency Ltd., 70 Victoria Street, London, S.W.1. Tel. VICtoria 9132.

National Boat Show, 11th Annual.—Fri., 28 Nov., to Sun., 7 Dec., at the National Guard Armory, Seattle. Organised by the Northwest Marine Industries, Inc., Marina Mart, 1500 Westlake Avenue North, Seattle.

American Association for the Advancement of Science.—Fri., 26 Dec., to Wed., 31 Dec., at Washington, D.C., U.S.A. Offices of the Society: 1515 Massachusetts Avenue N.W., Washington 25, D.C., U.S.A.

***Nuclear Fuel Cycles, Symposium.**—Thurs. and Fri., 22 and 23 Jan., 1959, in London. Organised by the Institute of Physics (one of the constituent bodies of the British Nuclear Energy Conference.) Offices of the Institute: 47 Belgrave Square, London, S.W.1. Tel. BELgravia 6111.

***Hardware Trades Fair, International.**—Mon., 2 Feb., to Fri., 6 Feb., 1959, at Olympia, London, W.14. Organised by Universal Exhibitions, 74 Holland Park, London, W.11 Tel. PARk 7360.

***Iron and Steel Industry in India, Symposium.**—Wed., 4 Feb., to Sat., 7 Feb., 1959, at Jamshedpur. Organised by the National Metallurgical Laboratory, Jamshedpur 7, India.

***Smallwares Trade Fair, Sixth.**—Mon., 2 Mar., to Fri., 6 Mar., 1959, at the Hotel Metropole, Brighton. Organised by Trade and Technical Exhibitions Ltd., 1 Dorset Buildings, Salisbury Square, London, E.C.4. Tel. FLEet Street 1555.

***Atom Fair and Nuclear Congress.**—Sun., 5 April, to Fri., 10 April, 1959, in the Public Auditorium, Cleveland. Organised by the International Atomic Exposition Inc., 117 South 17th Street, Philadelphia 3, Pa., U.S.A. Co-ordinating body: Engineers' Joint Council, 29 West 39th Street, New York 18, U.S.A. (Additional information.)

EUROPAK

***Packaging Exhibition (EUROPAK 1959).**—Tues., 21 April, to Tues., 28 April, 1959, in Amsterdam. Offices: Tesselschadestraat 5, Amsterdam, Holland.

Instrumentation and Computation in Process Development and Plant Design, Symposium.—Mon., 11 May, to Wed., 13 May, 1959, in London. Organised by the Institution of Chemical Engineers, the Society of Instrument Technology and the British Computer Society. Address of the Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1. Tel. BELgravia 3647.

***Photo Fair, International.**—Mon., 11 May, to Sat., 16 May, 1959, at Olympia, London, W.14. Apply to British Organisers Ltd., 52 Grafton Way, London, W.1. Tel. EUSton 7930.

***Heating, Ventilation and Air Conditioning, International Conference.**—Mon., 25 May, to Wed., 27 May, 1959, in Paris. Organised by the Institut Technique du Batiment et des Travaux Publics, 6 Rue Paul Valéry, Paris 16e.

***Business Efficiency Exhibition, 46th.**—Mon., 25 May, to Thurs., 4 June, 1959, at Olympia, London, W.14. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate Hill, Cannon Street, London, E.C.4. Tel. CENtral 7771.

***German Handicrafts and Trade Fair.**—Wed., 27 May, to Sun., 7 June, 1959, in Munich. Offices: Theresienhöhe 14, Munich 12, Germany. *Agent:* Mr. Neven du Mont, 123 Pall Mall, London, S.W.1. Tel. WHItehall 8211.

***Shaft Sinking and Tunnelling, Symposium.**—Wed., 15 July, to Fri., 17 July, 1959, at Olympia, London, W.14. Organised by the Institution of Mining Engineers, 3 Grosvenor Crescent, London, S.W.1. Tel. BELgravia 3691.

***Packaging Exhibition, Sixth.**—Tues., 8 Sept., to Fri., 18 Sept., 1959, at Olympia, London, W.14. Organised by Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester. Tel. Deansgate 6363.

Plastics Industry International Fair ("Kunststoffe 1959").—Sat., 17 Oct., to Sun., 25 Oct., 1959, at Düsseldorf. Organised by the Nordwestdeutsche Ausstellungs Gesellschaft m.b.H. (NOWEA), Ehrenhof 4, Düsseldorf, Germany.

Book Reviews

UNCERTAINTY IN METAL CUTTING

Performance of Metal-Cutting Tools. By R. TOURRET. *Butterworths Scientific Publications, 88 Kingsway, London, W.C.2.* (50*s.*)

Metal cutting science is at the present time in a very confused and conflicting state. To write a complete and uncontroversial book on this subject at the moment is virtually impossible. This is due to the considerable differences between observed phenomena and the predictions of existing theories. Even if some of the theories proposed were correct, it is doubtful whether their application would gain full approval in practice due to their complexity. No simple theory is ever likely to account for the behaviour of a cutting tool exactly because of the very many factors which would have to be correlated. It is certainly true therefore that if we require to solve any current metal-cutting problem an inevitable recourse either to empirical information or direct experience must be made.

It is clear that the problem of producing an adequate book on the subject within the limitations of present knowledge is not to be treated lightly. To produce a balanced product demands that the author have very wide experience, both in the practical and theoretical fields, so as to be able to state clearly and simply the bases and assumptions of the various theoretical approaches and to differentiate between the results of these idealised assumptions and real cases. If this is not done really well, the uninitiated reader cannot decide what information is exact and what is not. Although this book contains a very great amount of valid information extracted from various research publications, what is true theory and what is observed fact, is not clearly stated. In fact the chapter on "Theory of Continuous Chip Formation" consists, in the main, of results from practical tests and is not an adequate discussion of the present state of metal-cutting theory at all.

The presentation of graphical information in the book is of a good standard and clear reference to the source of the information in the list of references enables the reader to look into any matter in more detail if necessary. The conditions under which each test was carried out are given very clearly in the captions to each diagram. The sequence of chapters seems a little odd, for example, one can find three distinct chapters labelled "Lubricant". It would surely have been better to confine the discussion of lubricant to one complete chapter. However, a little patient use of the index enables the desired information to be traced.

In the foreword it is stated by the author that "the book is not a practical workshop manual"; on reading the text one can certainly say that it does contain a lot of information from many diverse sources on the effect of different variables on the cutting process. The author himself admits that "it is too much to hope that this book is free from errors" thus indicating that he realises the possible shortcomings of such a book based on the present state of knowledge in this field.

This is a book with a lot of tabulated and graphically expressed information and practising engineers with some knowledge of the subject could find it a handy reference book in this respect. Unfortunately the more fundamental aspects of the problems involved are not adequately discussed and, therefore, it would not be suitable as a student text book.

NEW BOOKS

British Coal Mining Explosives. By JAMES TAYLOR and P. F. GAY. *George Newnes Limited, Tower House, Southampton Street, Strand, London, W.C.2.* (27*s.* 6*d.*)

Hitherto, the development of British coal mining explosives, and the accessories used with them, has not been covered in any single book. The authors have produced this book to fill the gap. It is intended for mining engineers and the mining community as well as for those in the explosives trade. They trace the history of coal mining in Great Britain; the use of gunpowder in blasting; the development of modern explosives in coal mining; British gallery testing; law in relation to explosives for coal mining; the design and characteristics of detonators; the development of Eq.S explosives; combined blasting and water infusion for coal breaking; the choice of explosives for use in coal mines; blasting devices such as Cardox, Hydrox and Airdox; opencast coal mining and the mechanism of blasting coal and rock. A comprehensive index is provided.

Long-Wave and Medium-Wave Propagation. By H. E. FARROW. *Iliffe and Sons Limited, Dorset House, Stamford Street, London, S.E.1.* (4*s.* 6*d.*)

The booklet is based on a series of lectures given at the B.B.C. Engineering Training Department to students specialising in the operation and maintenance of transmitting stations. It deals with ground-wave propagation; geological correlation; propagation curves; recovery and loss effects; mixed-path propagation; synchronised group working; low-power installations; ionospheric reflection; fading; the reduction of surface area by sky-wave; and long-range interference by sky-wave. A table of B.B.C. transmitting stations operating in 1957 is given in the appendix.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Machine Tools

VDF News. HEIDENREICH AND HARBECK, Werkzeugmaschinenfabrik, Hamburg 33. A regular bulletin of news and information concerning the products of the VEREINIGTE DREHBANK-FABRIKEN group. Number 14 contains accident prevention notes for machine tools.

Multi-Slide Press. ROCKWELL MACHINE TOOL COMPANY LIMITED, Welsh Harp, Edgware Road, London, N.W.2. "U.S." multi-slide machines for the production of intricate stampings in one operation. Model 28 has a feed of 8 in for a maximum width of stock of 1½ in; and model 35 a feed of 13 in and stock width 3 in. Leaflet.

Hand Tools. JOHN PEACE (STEEL AND TOOLS) LIMITED, Algoma Works, Sheffield 3. Files of all types, hacksaws and shears. Catalogue.

Universal Hobber. DOWDING AND DOLL LIMITED, 346 Kensington High Street, London, W.14. The V8 universal gear hobber for spur, helical and worm wheels. Capacity: spur gears up to 8 in diameter; length of hobbing traverse 7¼ in; maximum pitch in steel (one cut) 14 DP. Brochure.

Rotary Index Table. CENTEC MACHINE TOOLS LIMITED, Hemel Hempstead, Herts. Auto-pneumatic precision rotary indexing table; 16 in diameter giving 60 different index angles without change of plates—any angle divisible by 3 up to 180°. Maximum error of arc 5 sec. Hydraulic dashpot controls speed of operation; angle set by a button in a slot. Leaflet.

Magnetic Chucks. PANTON AND WEBB, Lavender Hill, Tonbridge, Kent. "Fimax" magnetic chucks for general use. Various sizes; angular adjustments, tilting adaptors. Leaflets.

Bandsaw. CATMUR MACHINE TOOL CORPORATION LIMITED, 103 Lancaster Road, Ladbroke Grove, London, W.11. Barnaby horizontal bandsaw cut-off machine; will handle the range normally dealt with by a reciprocating hacksaw. Capacity for sections up to 10 in diameter or 16 in by 6 in rectangular. Downfeed by hydraulic damper cylinder. Four cutting speeds. Leaflet.

On the Shelf

By Frank H. Smith

Rowse Muir Publications are producing *Control* (Volume 1, No. 1, July 1958) to cater for all aspects of this multi-application subject. The price is 3*s.* 6*d.*, and an idea of the field is given by the following titles from No. 1—"Electronic Systems for Industrial Measurement and Control, Part I"; "Dynamics of Mechano-Pneumatic Systems"; "What is Control Engineering?" (this is useful if you are going to subscribe); "Computer Control of Machine Tools"; "An Elementary Survey of Digital Codes." A useful feature of the first number is a buyers' guide which can also be bought separately for 3*s.* 6*d.*

That disher-out of funds for research, The National Science Foundation (Washington 25, D.C.) is responsible for "A Selected Bibliography of Research and Development and its Impact on the Economy" and if you are inclined to say "Economy of what?", say so by all means, but I cannot give the answer. Presumably that of the 49 United States. Maybe this bibliography is what convinces the N.S.F. that thousands and thousands of dollars spent on research is not so much wasted money. The booklet has 22 pages, an index of authors, a list of periodicals cited and no price marked on it.

The Microcard Foundation, Box 2145, Madison 5, Wisconsin, sends me three leaflets which are obviously identical triplets since they all tell me that one can buy NACA (National Advisory Committee for Aeronautics) Technical Notes in microcard form from numbers 2548 to 3488 for 499 dollars. Lesser quantities cost less money but it is not worth my quoting because if you want one you will want the lot. Incidentally, I have seen a hint that NACA will soon be abbreviated to NASA—something connected with a change of title to include Space Technology. I hope they have considered the implications of using the abbreviation as a word.

Mechanical Engineering (United States) carries, in its June number, its annual "Review of Heat Transfer Literature" for 1957. This has appended a long list of references, sub-divided into 14 applications.

A useful little catalogue is "Oxford Reference Books." An Oxford University Press production (though I received mine from Heffer) it lists the O.U.P. reference books covering 18 different categories. With it, Heffer sent me one of their specialist book lists and No. 36 of their *Book Adviser* for the spring. This lists recent publications subject-divided into 18 categories of the arts and humanities.

From the Chambre Syndicale des Producteurs d'Aciers Fins et Speciaux, 12 Rue de Madrid, Paris (8e), has come a copy of "Aciers de Construction, Non Alliés et Alliés Speciaux pour Traitement Thermique." It is, naturally, concerned with carbon and alloy engineering steels to French specifications.

A 12-volume edition of the *Soviet Historical Encyclopaedia* is to be published between 1959 and 1963. Initially that was all I was going to tell you but how can I keep to myself the fact that it will attempt to present reference material on the history of every country in the world, from primitive society to the present day. Twenty-five thousand articles long, it will be prepared by the Department of Historical Sciences of the USSR Academy of Sciences. E. Zhukov has been appointed editor-in-chief. So you've got a year to learn Russian in time for the first volume.

The National Physical Laboratory has issued the first quarterly list (for January to March 1958) of papers published. This periodical, as I have remarked before—at least I think I have—lists not only the material actually published by the NPL and its adjunct, the Aeronautical Research Council, but also material that has been published in other places by members of the staff.

Research and Development

HIGH SPEED FLIGHT,

An Introductory Talk

By Professor W. J. Duncan, C.B.E., D.SC., F.R.S.
University of Glasgow

A VERY young child sees things move through the air without knowing that the process involved in the motion is very different for a bird and a stone. At a slightly later stage he comes to realise that the bird keeps itself in the air by flapping its wings and can remain in the air as long as it wants while the stone is passive and has a limited path through the air. In fact it becomes " second nature " to regard flight and projection as entirely distinct affairs and there is indeed some justification and convenience in treating these as independent ways of moving through the air. On the one hand we have insects, birds, bats, aeroplanes, helicopters and, on the other, projected stones, arrows, bullets, shells. However, the distinction is not absolute, for many aeroplanes are catapulted into the air while projected bodies may be subject to aerodynamic lift forces as well as to resistance (drag). It is also a historical fact that in the very early days of powered flight there was sometimes real doubt whether a hop in the air was genuine flight or mere projection, but this doubt was unequivocally resolved when engines of improved power-weight ratio became available. The point of contemporary interest is that, with the speeds which can now be attained, the sharp distinction which used to exist between flight and projection has largely disappeared. For example, some engineers are already beginning to think, and not merely to speculate, about the possibility of projecting passengers to the antipodes in a vehicle which would make an aerodynamically controlled descent.

FUNDAMENTALS OF PROPULSION

A few words must be said here about the propulsion of vehicles through the atmosphere and in space. There are just two practicable ways of obtaining a propelling force and these are (*a*) by use of gravity, i.e., by running downhill, and (*b*) by projecting matter backwards. Method (*a*) can only be used after altitude has been gained by some means which, in practice, is by method (*b*). There are two important variants of method (*b*). First, the propulsive apparatus accepts atmospheric air and ejects it backwards with increased velocity; again, this can be done in two fairly distinct ways, namely, by means of a screw propeller driven by a piston engine or turbine, and by the propulsive jet of a turbo-jet engine (these are combined in the turbo-prop unit, with the propeller predominant, and in the ducted fan engine). The first method (that of " air swallowing ") is only available within the atmosphere and becomes progressively more difficult at increasing altitude. Second, the matter ejected backwards comes entirely from a store carried in the vehicle and the necessary high velocity of ejection is obtained by combustion of the stored matter itself—this is rocket propulsion. In every case there must be, in effect, a supply of fuel and of oxidant, although a solid rocket fuel is compounded of both of these. Both air-swallowing engines and rocket motors have limited operational endurance because both depend on the combustion of carried fuel. Otherwise, their characteristics are very different. Typically, the air-swallowing engine gives a moderate thrust for a long time, whereas the rocket gives a thrust which is enormous in relation to its own weight for a comparatively short time. The rocket motor is the only propulsive unit, at present available, which is effective outside the atmosphere.

What is meant nowadays when we speak of " high-speed " flight? The answer is that the " yard stick " for speed is the natural one provided by the speed of sound in the atmosphere and that flight speed is high when it approaches or exceeds the speed of sound. It should be noted, in passing, that the speed of sound in the atmosphere is not constant but is proportional to the square root of its absolute temperature. The measure of flight speed in terms of the speed of sound, i.e., the ratio of the speed of flight to the speed of sound in the undisturbed air in the neighbourhood, is called the Mach number, often conversationally shortened to " Mach." When the Mach number is less than unity the flight is called " subsonic," whereas it is " supersonic " when the Mach number exceeds unity. The term " transonic " is applied to flight speeds near " Mach One " with the implication that there is some local supersonic flow near the surface of the aircraft. The adjective " hypersonic " is applied when the Mach number is 5 or greater.

HEAT BARRIER

Supersonic and hypersonic flight is characterised by the existence of a system of " shock waves " which spread out from the aircraft in a more or less well-defined conical shape; these waves are responsible for " supersonic bangs " and may do damage to buildings. Such three-dimensional waves are in some ways analogous to the two-dimensional surface waves which are generated by a ship moving through the sea and they are associated with an additional resistance called " wave drag." One of the most important aims of the designer of a high-speed aeroplane is to make this wave drag as small as possible. Another very important aspect of high-speed flight is " kinetic heating." The air in contact with the surface of the aircraft becomes heated and the effect is greatest at the most forward parts of the surface. A close estimate of the temperature increase is obtained from the equation that the rise in degrees centigrade at the nose of the body is equal to the square of the speed measured in hundreds of miles an hour. For example, when the speed of flight is 700 m.p.h., the temperature rise is 7 squared, or 49° C. This rises very rapidly with the speed and at 2,000 m.p.h. the temperature rise is 400° C. Kinetic heating is thus obviously a most important effect which presents the designer of any high-speed aircraft with difficult problems of protection and cooling.

Another aspect of kinetic heating, which is accentuated when the atmospheric density is very low, as it must be in high supersonic and hypersonic flight, is that the atmospheric air becomes dissociated to some extent and perhaps ionised. This is accompanied by deviations from the laws of perfect gases so that calculations about flow become more complex and difficult. When the air density is extremely low, as at altitudes exceeding, say, 100,000 ft, the air ceases to behave as a viscous fluid and its motion near the surface of the moving body becomes modified. First, there is what is called " slip-flow " and, at still lower densities, free molecular or Newtonian flow. An intercontinental missile with a range of the order of 5,000 miles travels for the greater part of its journey in a region where the air density is exceedingly low and the resistance to motion correspondingly negligible. While in this region, the missile requires no propulsion and it may legitimately be regarded as a satellite of the earth with an orbit whose perigee is below the earth's surface. The main problem is to get the missile down to earth without destruction by the very severe kinetic heating which occurs when it falls through the atmospheric layers at a speed which is initially exceedingly high but falls as regions of higher atmospheric density are penetrated. The intercontinental missile and the free satellite which can circle the earth (or perhaps escape from it) both attain a velocity which is eventually extremely high but is attained in successive stages of acceleration by a multiple rocket system. Since the velocity in the lower and denser part of the atmosphere is comparately low the kinetic heating problem for this part of the flight is not very difficult to overcome.

DIRECTION CONTROL

An aeroplane is usually controlled by moving hinged flaps which are attached to the wings or tail unit; these are familiar as ailerons, elevators and rudders. A hinged flap is effective for control because it changes the aerodynamic forces on the aeroplane when it is turned on its hinge axis. However, such a flap becomes totally ineffective for a body which has reached an altitude where the air density is negligible. How, then, can the body be controlled? The answer is by ejecting matter in the direction opposite to that in which it is desired to move; the attitude of the body can also be changed by this means. In practice, this involves control by suitably arranged small jets, but during the stage when propulsive rockets are still operative some control can be got by changing the direction of the main rocket jet, either by deflecting plates or by swivelling the whole combustion chamber.

A manned aircraft may be guided by the pilot who uses the controls of the aircraft to change its attitude, direction of flight and speed in the ways he desires. However, the pilot needs navigational aids and these become obligatory for " blind " flying and for long-distance flying in general. An unmanned missile must obviously be provided with a guidance system as well as with adequate controls. The guidance may be provided by radar or by " inertia navigation."

It is of great interest that aeronautics and astronomy have met in the new subject of astronautics. This is not a mere matter of science fiction. There is no doubt at all that satellites are very important instruments of scientific research and their potentialities are only beginning to be appreciated.

* Papers read before Section G of the British Association at Glasgow on Thursday, 28 August, 1958.

ENGINEERING PAPERS AT THE B.A.

The British Association began this year's meeting on Wednesday, 27 August, with the Presidential Address " Science and Business: a Balanced Partnership," by Sir Alexander Fleck, F.R.S. The meeting is being held at Glasgow.

Section G (Engineering) meetings opened on the following morning with two papers dealing with high-speed flight, long-range rockets and satellites. These papers, by Mr. L. F. Nicholson and Mr. E. C. Cornford, both of the Royal Aircraft Establishment, Farnborough, together with an introductory talk by Professor W. J. Duncan, are published on the following pages.

As has been the custom for very many years, ENGINEERING has again prepared, where possible, preprints of the papers read before Section G. These preprints are distributed to those attending the session and the papers are then published, in full, in ENGINEERING. This practice will be followed this year, and in next week's issue there will appear " Nuclear Propulsion," by Mr. J. Edwards, head of the Naval Section, AERE, Harwell, and a group of three papers " Radio Aids to Navigation," by Dr. R. L. Smith-Rose and Dr. B. G. Pressey, of the Radio Research Station, and Mr. Caradoc Williams, of the Radio Division, RAE, Farnborough. The other papers will then follow in later issues.

ROCKETS AND SATELLITES*

Aerodynamic Aspects of High Speed Flight

By L. F. Nicholson,
M.A., F.R.Ae.S.
Head of the Aerodynamics Department, R.A.E., Farnborough

AT THE present time the aeronautical field is opening up in a most exciting way. After fifty years given over in the main to exploitation of the conventional aerofoil and the study of more or less two-dimensional flows, we are starting to exploit more complex three-dimensional flows to an ever increasing extent as the possibilities opened up by the jet engine and rocket are explored.

The jet engine and rocket have made possible supersonic and hypersonic flight. Now aerodynamic developments, involving the sorting out and understanding of complex three-dimensional flows and of the problems of aerodynamic heating, are on the way to turning these possibilities into realities. At the same time advances in the theory and practice of automatic control are leading towards automatic landing and to artificial aids to stability which widen the practical range of aircraft shapes. Advances in control and in propulsion techniques make vertical take-off and landing practicable, while avoiding many of the limitations of helicopters. With all these fields opening up, the choice of themes for this paper is difficult, but since speed, after all, has always been the main commodity, though not the only one, which air transport has had to offer, it seems appropriate to review the aerodynamic field in terms of speed; that is, review the changing problems which appear as we strive to go faster.

THE POINT OF SPEED

The ultimate demand for higher speeds in aircraft, civil or military, manned or unmanned, seems assured, though choosing the moment when the time is ripe for any step upwards in operating speeds is a matter calling for the nicest judgment. Particularly when questions both of technical feasibility and economics are involved.

The advantages of higher speeds in transport are probably better illustrated in terms of the increase in the number of places brought within range of a one-day visit, or a business trip with only one night away from base, than in the saving of airborne time. For example if we take 12 hours away from base as a time not likely to discourage anyone from making a visit of some importance during a day, take 4 hours for incidental travel, 5 hours to do the day's work at the far end, leaving $1\frac{1}{2}$ hours each way for the main air journey, the distance over which useful day visits can be made rises from 300 to 400 miles for current timetables to about 700 miles for the high subsonic speed jets, 1,500 miles for the sort of supersonic jets which are technically and probably economically feasible starting now, and 4,500 miles for what look at present like the ultimate limits in cruising type flight. Indeed the range covers the whole world if rocket flight is ever harnessed to transport.

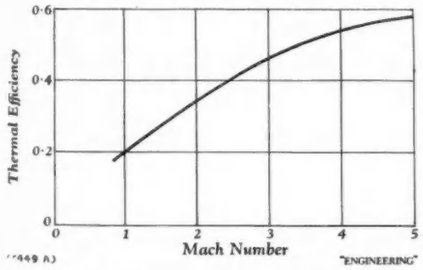


Fig. 1 The possible rise in thermal efficiency of a jet engine having an efficient intake with increasing flight speed.

Fig. 2 Typical supersonic air intake.

Fig. 3 An example of shaping to obtain aerodynamic efficiency at low supersonic speeds.

In quoting these figures it is not suggested that passenger transport at the highest speeds mentioned is just round the corner—it may never become economic. They are quoted just as an illustration of the fact that really high-speed transport will have some attractions if and when it comes, at least in the business and administrative fields. The subtleties of personal contact and personal negotiation are such that it seems likely that whatever advances the communications engineer may have to offer, there will be a market for " business " travel, using the phrase in a wide sense, at any speeds which may become feasible.

So much for the case for seeking ever-increasing speed in air transport. Let us now look at the technical feasibility and the picture that is opening up. Quite apart from what the customers want, there are sound scientific reasons for trying to fly fast, in addition to the obvious fact that many of the costs involved in air travel are fixed costs per hour, and not per mile, so that speed pays. One dominating factor in favour of high speed arises from the characteristics of jet engines. The essence of a jet engine is that air is compressed, heated and expanded; if the aircraft is flying fast the impact of the aircraft on the air is sufficient, with a suitably designed air intake, to give a high degree of compression to the air, thus considerably increasing the thermodynamic efficiency of the engine. The increase of efficiency with speed is the main reason why subsonic jets are normally designed to cruise as fast as is possible without serious drag rise, and loss of aerodynamic efficiency. But with a good intake design, the efficiencies achievable at high supersonic speeds are really of great significance and are probably the key factors in making supersonic flight an economically reasonable proposition. Efficiencies exceeding those of good modern diesel engines or the latest steam power stations, are within the realm of possibility, as shown by Fig. 1. Of course such efficiencies are not obtained by the simple forward-facing hole which can be an efficient inlet at subsonic and low supersonic speeds. Subtleties of shaping are required to get high efficiencies and to combine them with low drag, to avoid unstable pulsating flows and to maintain high efficiency over a wide speed range. Given half a chance, the high-pressure air collected by the intake will blow back through the " tired " air slowed by scrubbing the surfaces of the air intake, and air intake design for really high speeds is one of the most exacting of aerodynamic tasks. Typical of the sort of shapes developed are the intake models shown in Fig. 2.

AERODYNAMIC SHAPE

We have shown briefly how increasing speed leads to increasing efficiency up to very high speeds indeed, and it may well be asked whether the air traveller is going to be whisked around at very high supersonic speeds whether he likes it or not, not for his own convenience, but for that of the airlines. The answer of course is that the rise in efficiency of the intake as speed increases can be offset, or if we are not careful completely swamped by the extra drag associated with shock waves in supersonic flight.

A measure of the efficiency of an aerodynamic shape for cruising flight is the ratio of the weight of the aircraft to the engine thrust required. The peak of aerodynamic efficiency, as defined in this way, is achieved in specialised

sailplanes where a peak value of over 30 has been achieved, but normal well-designed subsonic transport aircraft reach efficiencies up to about 20. If a typical subsonic aircraft were to be made supersonic by brute force, by providing enough thrust to drag its unsuitable shape through the air at supersonic speeds, the efficiency would show a catastrophic drop near the speed of sound to perhaps one-tenth of its subsonic value.

Aerodynamic research over the past few years has shown two possible areas of improvement over this disheartening picture. First, by really understanding the complex airflow around highly swept wings they can be designed as lifting surfaces, with precisely chosen camber and twist so that each part carries its chosen element of lift; furthermore, we can design the whole wing, fuselage and engine installations not just as efficient units, but as part of a single whole, each unit being designed to achieve full efficiency, not when operating in undisturbed air, but operating in the flow field induced by the remaining parts of the aircraft. An example of a wing and body so designed is shown in Fig. 3. In this way the high efficiencies associated with subsonic flight can be carried over, not unimpaired, but without a catastrophic drop, to low supersonic Mach numbers, up to about 1·3. This is illustrated in Fig. 4 and also in Fig. 5 where the efficiencies of Fig. 1 and Fig. 4 are combined into a single figure of merit. At higher supersonic speeds one approach to the problem of avoiding too serious a drop in efficiency is to thin the wing and tail surfaces and draw out the body lengthwise into a very long slim shape.

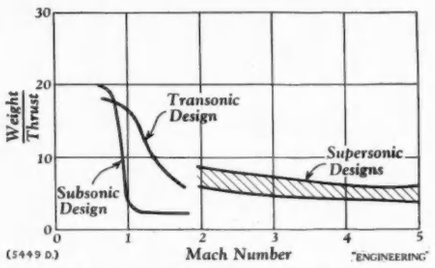


Fig. 4 Cruising efficiencies of typical aircraft for speeds ranging up to Mach 5.

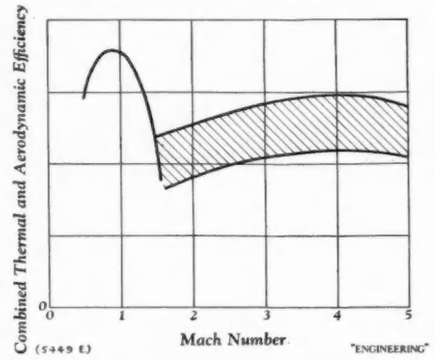


Fig. 5 Overall efficiency of aircraft and propulsion system over the speed range up to Mach 5. This illustration is a combination of Figs. 1 and 4.

SLENDER WINGS

In these sorts of ways, at the cost of introducing structural engineering problems, considerable improvements are possible and plausible supersonic aeroplanes can be envisaged, as is shown by the lower bound of shaded area in Figs. 4 and 5. However, a further increase in aerodynamic efficiency would make a tremendous difference to the attractiveness of supersonic transport, and this has stimulated research into a wide range of possible shapes, probably the most important of which fall into the general class of "slender wings"—wings which are long compared with their breadth, have highly swept leading edges and generally combine the stowage function of a fuselage with the lifting function of a wing in a single shape. Methods of designing such wings for high aerodynamic efficiency have been developed, in combined theoretical and experimental researches, and many subtle variations in planform, varying considerably from the simple delta, are possible, as well as cambered and twisted surfaces designed to give nearly ideal load distribution. An example is shown in Fig. 6.

Such slender wings are by no means the only approach to efficient cruising at supersonic speeds, but they do give the promise of supersonic transports really competitive with subsonic designs. These wings exhibit flows of great complexity at high-lift attitudes appropriate to low-speed flight, and set problems of static and dynamic stability demanding large-scale research for their solution. The complex types of flow with separation from the leading edge are illustrated in Figs. 7 and 8. In Fig. 7 condensation is used to show up the vortices springing from the leading edge of the wing and Fig. 8 uses oil to show the complex flow on the upper-wing surface. These complex flows lead to increases of lift compared with the types of attached flows considered in classical theory and the lift obtainable is therefore greater than might have been supposed. However, having probed into the problems it does appear that slender wings of this general type offer the prospects of raising the aerodynamic efficiency, as shown in the upper bound of the shaded area in Figs. 4 and 5, and allowing us to maintain an efficiency which, while lower than at subsonic speeds, is nevertheless high enough to be attractive up to quite high supersonic speeds. It must be emphasised, however, that the slender wing is only an example of the ways in which an imaginative aerodynamic approach, backed by large-scale research, can offer efficient supersonic flight and is only one of many approaches.

THERMAL THICKET

We have seen the combination of new aerodynamic shapes and the high engine efficiencies, made possible by efficient air intakes at high speeds, offer the possibility of flight at speeds well into the range where temperature rises due to air friction start to set formidable problems, and we must consider whether the upper end of the speed range discussed so far, with Mach numbers of 4 to 6, are ruled out for practical long-range flight by such heating.

It is easy to become frightened by the very high temperatures which are associated with such high speeds, but the temperatures normally quoted are those appropriate to a body in equilibrium with the air neglecting radiation. In practice, the air friction is always trying to raise the temperature towards this equilibrium value and radiation from the hot surface is trying to keep the temperature down. For any given case the rate at which heat flows in is proportional to the air density and the rate of heat loss is proportional to the fourth power of the surface temperature. These two facts—the very rapid increase of radiation from the surface with increasing temperature and the reduction in rate of heat input which goes with increasing altitude—suggest that if very high-speed flight is associated with very high altitudes, the surface temperatures may not be too great; in fact, it turns out that, without choosing cruising heights so great that the thin air demands excessively large wings to support an aircraft, temperatures can be kept down to the order of 600° C, even at the highest speeds possible for cruising flight. Such a temperature, while it sets formidable problems for manned flight, is certainly not so high that, with available structural materials and insulating and refrigerating techniques, the prospects for long-range transport are impossible up to Mach numbers of around five.

BALLISTIC FLIGHT

So far, we have seen the good prospects for economic supersonic transport at speeds of twice the speed of sound or more, and the more distant prospect of transport at speeds up to five times the speed of sound. If we look to still

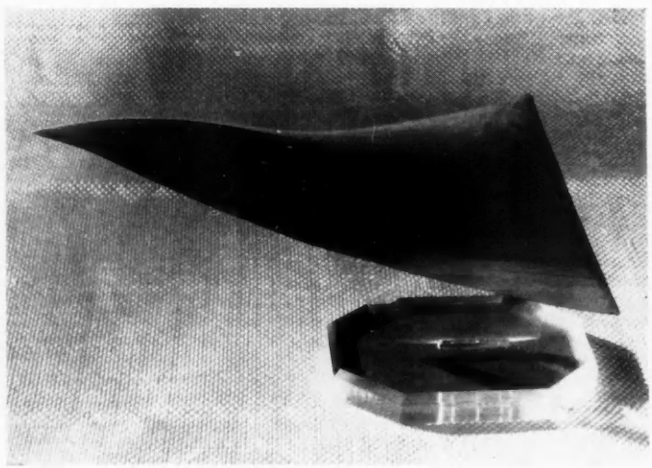


Fig. 6 An example of aerodynamic shaping for efficient lifting at supersonic speeds.

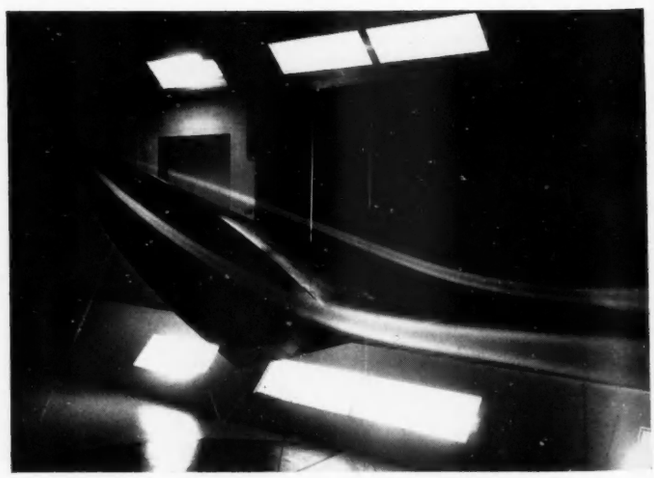


Fig. 7 The air flow over a wing of low-aspect ratio, as shown by condensation trails.

higher speeds, it is no longer even a reasonable approximation to consider only the constant-speed cruising phase of flight and ignore the acceleration and climb to height and the final glide to earth. At the higher cruising speeds the final gliding deceleration covers a significant distance compared with typical air-transport stages. A typical flight, instead of consisting of a climb, a cruise and a descent, is replaced by a climbing acceleration and a long decelerating glide.

At these speeds rocket propulsion, for which efficiency increases with increasing speed, takes over from the air-breathing engines. Typical ranges for a given top speed are shown in Fig. 9 and it will be seen that Mach numbers in the range of 7 to 12 are of interest for such rocket gliders. At such speeds the correct choice of height during the flight enables the full impact of kinetic heating to be avoided, though the shape of such an aircraft would be a compromise between the best shape for low drag—thin and pointed—and the best shape for avoiding hot spots—which would avoid points and sharp edges. The energy of fuel used in such flights goes almost entirely into building up the kinetic energy of the aircraft, rather than into potential energy in climbing to height or into air resistance. Hence, during the powered stage at least, lightweight is more important than low drag. Such very high-speed flight can only be achieved at a cost, but it is worth noting that the weight of fuel (including oxidant) used on a typical 3,000 mile flight need only be some twice the weight of fuel used in a crusing flight at supersonic speeds, and though rocket fuels are typically more expensive than normal jet fuel, hypersonic gliders are not right outside the bounds of economic sense in the longer-term future.

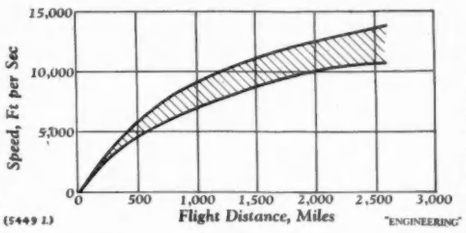


Fig. 9 The range or flight distance attainable from boost-glide aircraft having various maximum speeds.

MANNED RE-ENTRY

At these sort of speeds, say 10 times the speed of sound and upwards, appreciable ranges can be obtained in ballistic flight, largely outside the atmosphere and without aerodynamic problems save during the exit from and entry to the earth's atmosphere. But there are large provisos, at any rate as far as re-entry is concerned. Is re-entry from very high speeds corresponding to long-range ballistic flight or satellite re-entry bound to be associated with temperatures and loads which make manned re-entry a forlorn hope? If one looks merely at the equivalent in heat of the kinetic energy which has to be dissipated in slowing down from such speeds, as shown by Fig. 10, the prospect looks frightening. However, much of the energy can be diverted into heating the air rather than heating the aircraft. Even if all the deceleration of the aircraft took place through skin friction and the surface was cooled and maintained at normal temperatures, only about half the energy would appear in the body and half would be left in the wake. By consciously designing for low heat input, however, the proportion of heat absorbed to heat left behind in the wake might be reduced to, say, one-tenth. This is still a formidable quantity of heat, but much of this can be rejected by radiation with surface temperatures of a few hundreds of degrees centigrade, provided there is sufficient time allowed to reject the heat. For very steep trajectories little can be done to provide time, but for reasonably shallow trajectories the use of aerodynamic lift, precisely controlled, can give time for heat to be rejected, can stretch a re-entry time from seconds to minutes. At the same time the use of lift for this purpose can also reduce the deceleration to very modest values, not of the order of 6 to 8 g appropriate to fit and trained pilots, but to excess "g's" of less than one.

The limitation to shallow re-entry angles implies departure from the trajectory giving maximum range for a given speed, but not to such an extent as to rule out ballistic flight with manned re-entry. For example, as Fig. 11 shows, for ranges of 2,000 miles and upwards limiting re-entry angles to 20° needs less than an 8 per cent increase in speed above the optimum, while re-entry angles of 10° can be achieved with a 25 per cent increase of speed at 2,000 miles range, reducing to a 10 per cent increase at 4,000 miles range. No fundamental snags in ballistic flight, including re-entry from satellite orbits have been shown up, but a mastery of high-speed aerodynamics—which is not easily acquired—is implied in the earlier statement that "the use of aerodynamic lift, precisely controlled, can give time for heat to be rejected" and so open the way for manned re-entry.

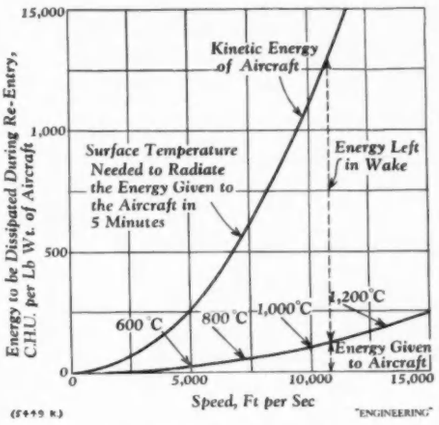


Fig. 10 Energy absorbed by an aircraft re-entering the atmosphere and typical surface temperatures needed to radiate this heat.

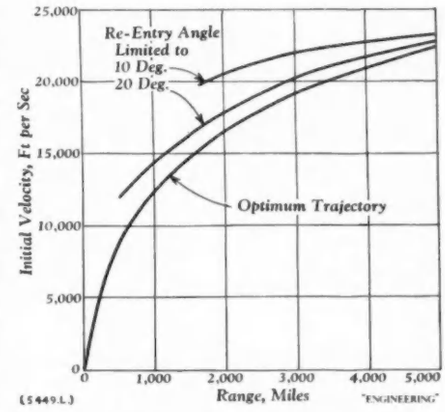


Fig. 11 Effect on velocity/flight-range curves of limiting the re-entry angles to ease the return of a ballistic aircraft into the atmosphere.

FUTURE RESEARCH

To the already expanding domain of aerodynamics another field is being added: the study of flows of such speeds and energies that the temperature changes in the air caused by the passage of the aircraft cause dissociation and ionisation of the air. The production of such high temperatures and high-speed flows in the laboratory involve new techniques, so that light gas guns, shock tubes and other devices take the place of the conventional wind tunnel, while the spectrographs and other stocks in trade of the high-temperature gas physicist appear alongside the aerodynamicist's manometers and balances. Many of the problems involved in such high-speed flows are only seen dimly, let alone solved, but the ground work is being laid particularly in developing experimental techniques and we can look forward to an ever increasing growth in knowledge in the realm of very high-speed aerodynamics.

Summing up, starting with the view that speed is one of the main things which air transport has to sell and that speed, at the right price, is saleable, we have seen, very roughly, some of the ways in which aerodynamic developments have led to the situation where supersonic transport, at speeds twice the speed of sound and more, is becoming possible with reasonable prospects for economy. Higher cruising speeds up to about five times the speed of sound are foreseen as technical possibilities, while further ahead study of rocket-boosted hypersonic gliders and ballistic aircraft shows up no sign of insurmountable technical barriers, though by present standards the difficulties of offering such travel seem formidable. Aerodynamic control of flight path offers a way of avoiding the fiery end which will attend most uncontrolled returns from satellite or near satellite speeds. Aeronautics is at present wide open to development in which aerodynamic art will have a great part to play.

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The particular problems of high-speed flight that are associated with long-range rockets and satellites are discussed in the following paper by Mr. E. C. Cornford, head of the Guided Weapons department, Royal Aircraft Establishment Farnborough.

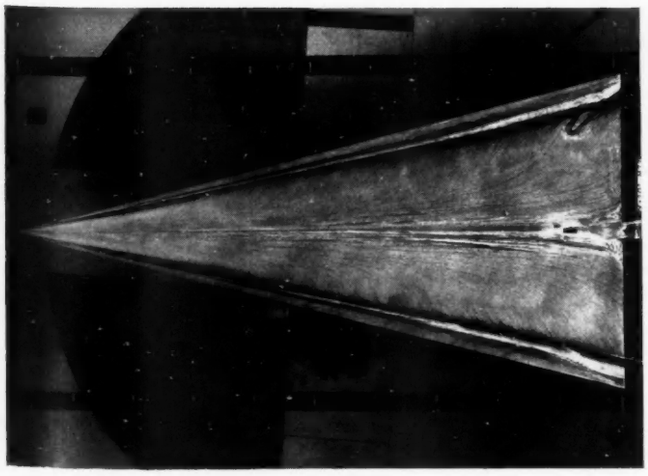


Fig. 8 Surface streamlines on the upper surface of a low-aspect wing, illustrating the complex nature of the flow.

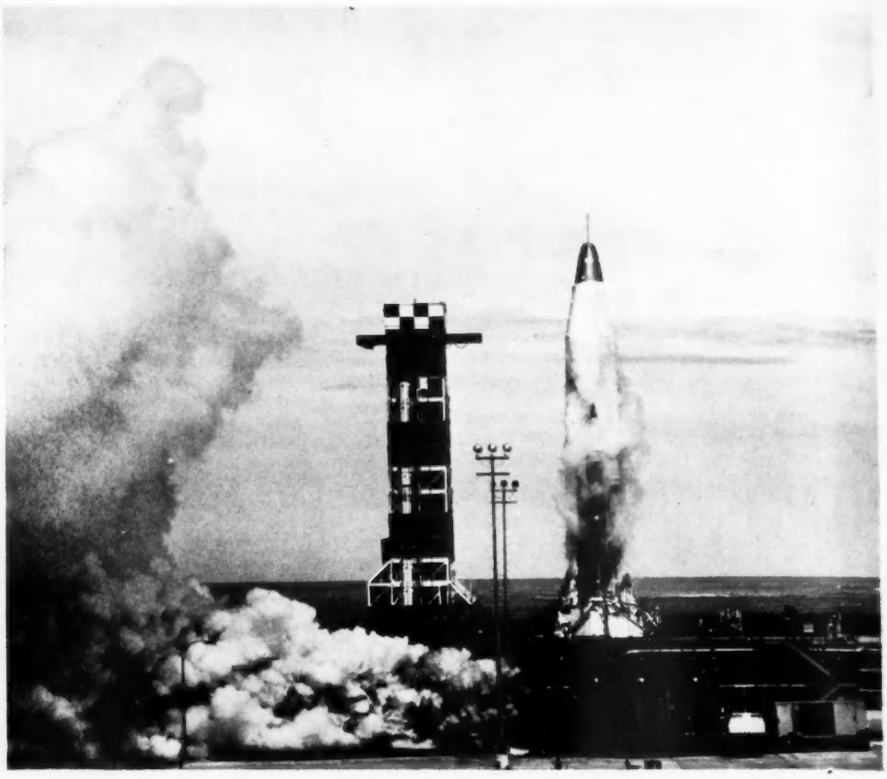


Fig. 1 Launching the 5,000 mile range U. S. A. F. missile Atlas. (U.S. Air Force photograph)

LONG-RANGE ROCKETS AND SATELLITES

Their Performance, Guidance and Control

By E. C. Cornford, B.A.

Head of Guided Weapons Department
R. A. E., Farnborough

IN A COMPANION paper on the previous pages, my colleague, Mr. Nicholson, has discussed aerodynamic aspects of high-speed flight. There is obviously a vast range of other aspects to be considered even when the high-speed vehicles are limited, as they are in this paper, to long-range rockets and earth satellites of the type illustrated in Figs. 1, 2 and 3. This present paper is concerned with some of the problems which have to be overcome in order to achieve guided and controlled high-speed flight with these devices. Two broad topics have been chosen for discussion. These are:

(i) The propulsive and structural requirements of long-range rockets and satellites, and

(ii) the problems of their guidance and control.

The flight pattern of a long-range rocket or satellite generally consists of a short period of powered flight, during which kinetic energy is built up to the level required to achieve the desired range, and while the missile climbs out of the earth's atmosphere so that its energy is not dissipated in overcoming air drag during the long period of coasting or ballistic flight that follows. Fig. 4 shows the variation of the minimum velocity at the end of powered flight—" all-burnt " velocity—with range over the earth's surface, for the typical values of rocket altitude at " all-burnt " marked along the curve. For short ranges, the maximum distance covered is given simply by v^2/g, where v is the " all-burnt " velocity and g the acceleration due to gravity. For missiles which travel over an appreciable fraction of the earth's circumference, range increases rather faster than the square of the " all-burnt " velocity.

Inset in Fig. 3 is a curve showing the variation of the velocity required for a circular satellite orbit with the altitude of the orbit. This is given by

$$V = \sqrt{\frac{g R^2}{R + H}} \quad . \quad . \quad (1)$$

where R is the radius of the earth, and H the height of the satellite orbit. Not all this velocity need necessarily be provided by the launching vehicle, since the earth's rotation can make a contribution, having a maximum of 1,500 ft per sec for a launching due east on the equator.

Propulsion to the " all-burnt " heights indicated on Fig. 4, or to satellite orbital altitudes is far beyond the operating capabilities of air-breathing engines and inevitably demands the use of rocket propulsion. The following section is concerned with the means by which rockets can achieve the required " all-burnt " velocities.

ROCKET PERFORMANCE

The " all-burnt " velocity V which could be achieved with a rocket having a single stage of propulsion may be written as

$$V = V_E \log_e \lambda - V_1 - V_2 \quad . \quad (2)$$

where V_E is the exit velocity of the rocket gases; λ is the mass-ratio, that is the ratio of the initial mass of the rocket to its mass at " all-burnt "; and V_1 and V_2 are the losses in velocity due to gravity and drag, respectively.

The values of the velocity losses V_1 and V_2 depend on the trajectory followed by the rocket during its powered flight, but for a large missile following a reasonably efficient climb path the loss due to drag should be less than 1,000 ft per sec, and that due to gravity rather less than 3,000 ft per sec. These two quantities may be regarded as fixed, so the velocity attained is determined by $V_E \log_e \lambda$.

Although in a given design V_E and λ are intimately connected, their effects on rocket performance can usefully be considered separately. Fig. 5 shows how the required value of λ varies with missile range for a value of V_E of 8,000 ft per sec, corresponding to a value of propellent specific impulse (V_E/g) of 250 sec, which is representative of current practice with liquid propellent rockets. This figure shows, for example, that for a single-stage rocket of range 3,000 nautical miles a mass-ratio of 14 is required. This implies that, at launch, propellents comprise more than 93 per cent of the missile all-up weight, leaving just under 7 per cent of the initial weight to cover the missile payload, structure, motor, guidance and control system, as well as any of the propellents which remain in the fuel pipes and pumps and cannot be burned. The motor itself can be expected to contribute 1 or 2 per cent of the initial weight, and it is most difficult to keep the structural contribution down to less than 5 per cent (compared with 30 to 35 per cent for aircraft), so that the fraction of the initial weight available for payload is very small indeed.

It is convenient to divide the initial weight of a rocket into three parts:—

W_1, the payload weight,
W_2, the weight of usable propellents, and
W_3, the weight of structure, motor, unusable propellents, etc.

Then $W_0 = W_1 + W_2 + W_3$, the initial all-up weight. The mass-ratio λ is then given by

$$\lambda = \frac{W_0}{W_1 + W_3} \quad . \quad . \quad (3)$$

Fig. 2 Final Assembly of the Vanguard satellite. (U.S. Navy photograph)

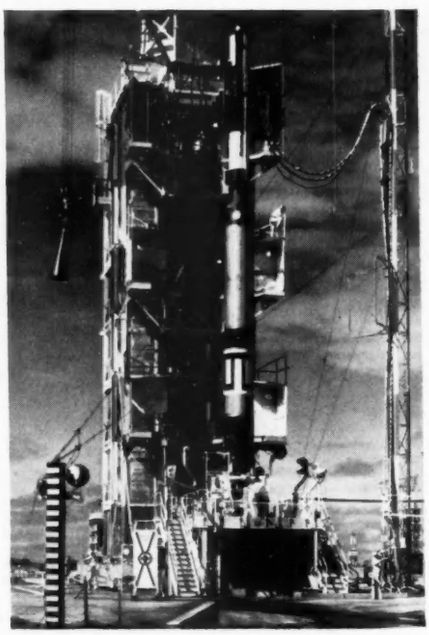
the payload ratio is defined as

$$W = \frac{W_0}{W_1} \quad . \quad . \quad . \quad (4)$$

and a structural efficiency factor ξ as

$$\xi = \frac{W_2}{W_2 + W_3} \quad . \quad . \quad . \quad (5)$$

Thus $(1 - \xi)$ is the fraction of the initial weight less payload available for structure, propulsion



system and unusable propellents. These three quantities are connected by the relationship

$$\left(1 - \frac{1}{W}\right) = \frac{1}{\xi}\left(1 - \frac{1}{\lambda}\right). \quad . \quad (6)$$

Fig. 6 illustrates this relation between W and λ for a range of values of ξ, and shows, for example, that in order to achieve the mass-ratio of 14 required for a 3,000 nautical mile range single-stage rocket, with a payload ratio, W, of not more than 50, a value of ξ of at least 0·95 must be achieved. The first ballistic rocket—the German V-2—had a mass-ratio of 3·7, a payload ratio of 12, and a value of ξ of 0·78.

The payload ratio, W, is very sensitive to changes in the design parameters. Fig. 7 shows the percentage change in W corresponding to a change of 1 per cent respectively in specific impulse, ξ, and in the required range. Thus, for a missile of range 3,000 nautical miles, a 1 per cent decrease in ξ (for W = 50, corresponding to a 20 per cent change in $(1 - \xi)$), leads to a 40 per cent increase in launching weight for the same payload weight.

Fig. 5 shows that, in order to achieve a range of 5,000 nautical miles in a single-stage missile, a mass-ratio λ of more than 20 is required, and earth-satellite velocities demand a value of nearly 30. Fig. 6, in turn, shows that mass-ratios of this order correspond to impractically high values of ξ—of the order of 0·97 to 0·98. To achieve performance of this order recourse must be had to more than one stage of propulsion, that is to systems in which two or more rockets are fired in succession, and as each burning stage is completed its empty propellent tanks and propulsion unit are discarded.

In a missile with n stages of propulsion, with the same efflux gas velocity in each stage, the velocity attained would be

$$V = V_E \log_e (\lambda_1 \lambda_2 \ldots \lambda_n) - V_1 - V_2 \quad (7)$$

when $\lambda_1 \lambda_2 \ldots \lambda_n$ are the mass-ratios in the successive stages. This velocity is roughly the same as that of a single-stage missile of mass-ratio $\lambda = \lambda_1 \lambda_2 \ldots \lambda_n$. Thus two stages each having a quite reasonable mass-ratio of 5 give roughly the same velocity as a single stage of mass-ratio of 25. It can readily be shown that, *in vacuo* and in the absence of gravity, the optimum multi-stage configuration, having the same structural efficiency in each stage, is one in which the mass-ratio, and hence the velocity increment, is the same in each stage. In most practical circumstances the most economic solution does not depart far from this condition. There is little advantage to be gained by using three stages if the task can be achieved with two, not only because of the additional engineering complexity, but also because if the number of stages is increased too far the result will be an increase in initial weight. This is because the time taken to achieve the final velocity increases with the number of stages and consequently the velocity loss due to gravity, V_1, increases.

Fig. 8 illustrates the effect of staging on the relation between the ratio of satellite weight to the all-up weight of its launching vehicle and the structural efficiency factor, ξ, assumed the same in each stage. This illustration shows, for example, that with a specific impulse of 250 sec and a value of ξ of 0·9, the optimum two-stage satellite-launching vehicle will have a payload ratio of more than 100, but that by the use of three stages of propulsion this figure can be reduced to about 65.

ROCKET STRUCTURES

The structure of a long-range rocket or of the launching vehicle for an earth satellite is simple compared with that of a modern aeroplane, but the need to obtain a structure weight amounting to only a very few per cent of the all-up weight makes just as stringent demands in design on weight economy and on materials. The main structural problem lies in the design of the integral propellent tanks which are thin-walled cylindrical shells having to withstand

(i) Compressive end loads from the motor and reactions from missile inertia and drag;
(ii) Shear forces and bending moments arising from the guidance of the missile, and from aerodynamic loads due to wind or gusts; and
(iii) Internal pressure due to the hydrodynamic heads of the propellants under axial acceleration, and possibly due to pressure in the gases above the liquids.

So far as the tank structure is concerned, the most interesting problem is the choice of the methods of stabilisation of the thin walls of the propellant tanks. This may be achieved either by internal pressurisation of the tanks or by mechanical means or by a combination of the two. Stiffening by pressurisation is obtained by applying an internal gas pressure to the tank, such that the longitudinal tension due to the pressure balances the maximum compressive end load. Such pressurisation exchanges longitudinal compression for hoop tension at the rate of two units of hoop tension for each unit of longitudinal compression relieved.

There are a variety of methods of mechanical stabilisation:—

(*a*) The use of a thick unstabilised uniform shell. This, though simple, is likely to be very heavy, and attractive only for rather small missiles, in which the greater curvature increases the buckling stress.
(*b*) Waffle-type construction. This offers a great improvement over a uniform unstabilised shell as a compressive member, and retains much of its simplicity. It requires extensive capacity for chemical or mechanical milling of large panels.
(*c*) Conventional aircraft skin-stringer-frame construction. And
(*d*) Sandwich construction.

There is no general answer to the choice between pressure and mechanical stabilisation, or between the different methods of mechanical stabilisation. The advantages and disadvantages need to be examined in detail for each application, and the choice, though primarily dictated by weight economy, may also be influenced by manufacturing considerations.

The main properties required of the constructional materials are high specific strength and stiffness, and the ability to maintain these over a wide temperature range. If, for example, liquid oxygen is chosen as the oxidant, it fixes the lower temperature limit at − 183° C and the upper limit will be set by considerations of kinetic heating during the rocket's ascent through the atmosphere. In addition the materials must be chemically compatible with both the fuel and

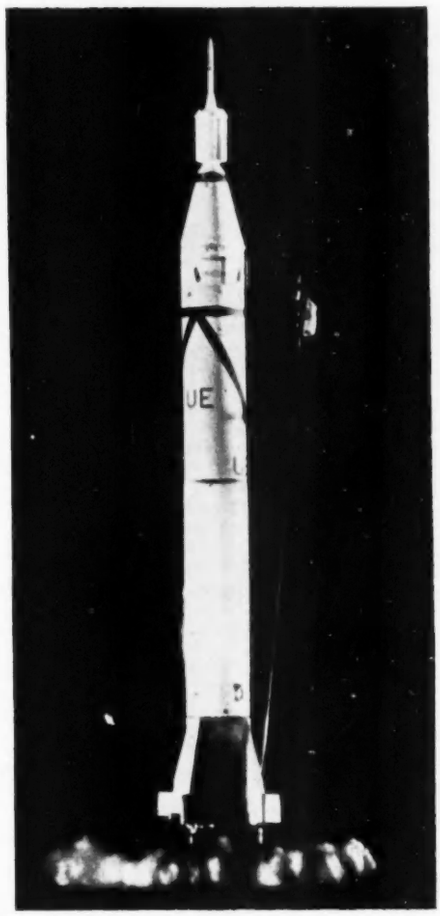


Fig. 3 (right) Launching of the first U.S. Explorer satellite. (U.S. Army photograph)

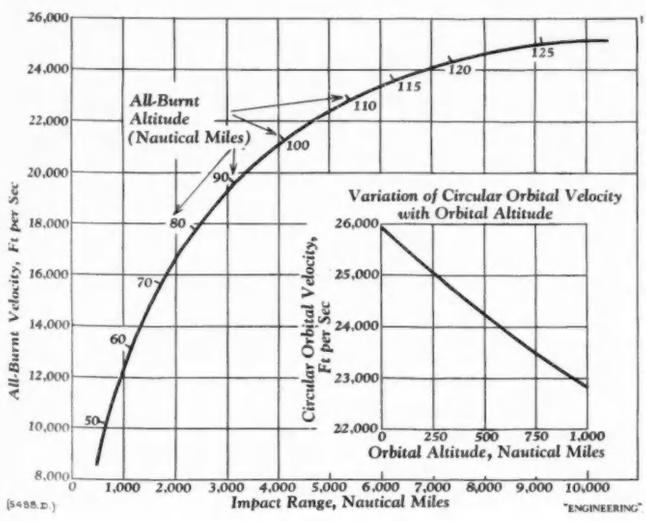

All-Burnt Velocity, Ft per Sec
Impact Range, Nautical Miles
All-Burnt Altitude (Nautical Miles)
Variation of Circular Orbital Velocity with Orbital Altitude
Circular Orbital Velocity, Ft per Sec
Orbital Altitude, Nautical Miles
"ENGINEERING"

Fig. 4 (left) Variation of "all-burnt" velocity with impact range for a long-range rocket.

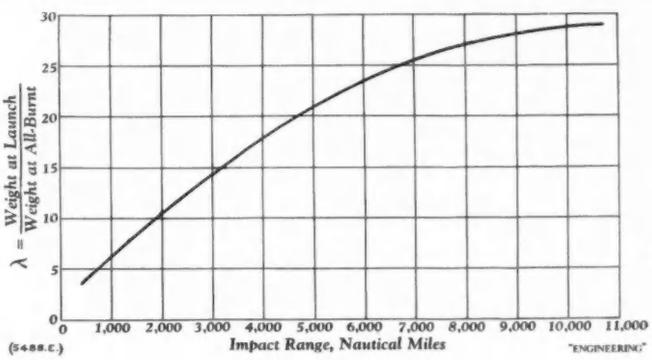


Fig. 5 (below) Variation of mass-ratio λ with impact range for a sea-level specific impulse of 250.

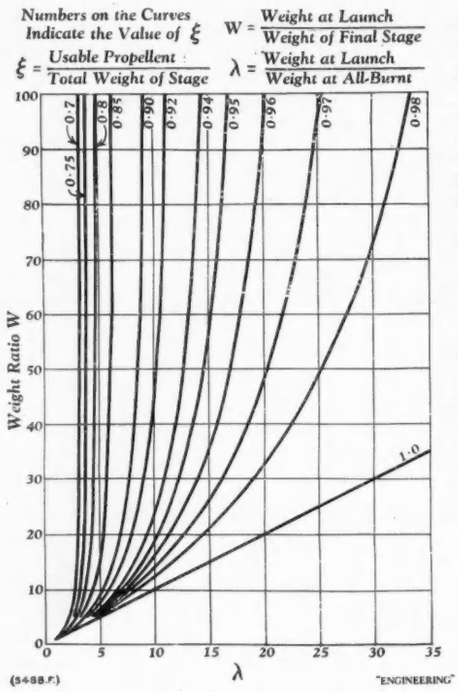


Fig. 6 Variation of weight ratio, W, with λ for a series of values of ξ.

oxidant, and be able to withstand the usual production techniques.

IMPROVING ROCKET MOTOR PERFORMANCE

Although the mass-ratio λ dominates the performance equations (2) and (7), they show that improvements in V_E or the propellent specific impulse, result in proportional increases in the velocity attained.

So far, in this paper, rocket performance has been based on a specific impulse of 250 seconds, a figure which can be achieved in practice with liquid oxygen/kerosine systems on which much experience in operation has been accumulating for some years. Considerably higher theoretical specific impulses are offered by various combinations of such oxidants as liquid oxygen, ozone and fluorine with such fuels as liquid hydrogen, ammonia, hydrazine, octane and the boron hydrides. For example, liquid oxygen and liquid hydrogen, at a mixture ratio of 3·5 to 1 by weight, give a theoretical specific impulse of just under 350 seconds, and the combination of liquid hydrogen with liquid fluorine or ozone gives still higher figures. However, the practical realisation of these high propellent performances raises a number of engineering and other problems. In almost every combination, one or other of the propellents is a particularly awkward liquid, because of its toxicity, its general instability or liability to detonation, or its corrosive properties, leading to serious problems in manufacture, storage and handling. The combustion temperatures of some of the combinations are very high compared with liquid oxygen and kerosine, and in order that the heat transfer and cooling problems of the thrust chamber should be held at a tolerable level some compromise in mixture ratio, and hence reduction in performance, would most probably be necessary.

It is a matter for debate whether the gain in specific impulse to be obtained from any of the higher performance propellents is worth the engineering effort required to make them a practical proposition, with the inevitably increased difficulties of handling and operation, or whether the more demanding requirements for long-range rockets and satellites are best met by "staging" with familiar and less unpleasant propellent combinations.

Fig. 9, which shows the variation of rocket range with mass-ratio for specific impulses between 225 and 350 seconds, gives a first indication of the advantage to be gained from improved specific impulse. It is, however, based on the assumption that any specific impulse in the range can be obtained with propellents having the same overall mean density as liquid oxygen/kerosine, and the real advantage to be gained from higher performance propellents depends not only on their specific impulse but also on their density. Since the weight of the tank structure will depend directly on the volume of the propellents, any reduction in mean density implies a corresponding increase in structure weight and a reduction in performance.

Except when liquid hydrogen is included, the majority of the high performance propellents have mean densities within ± 25 per cent of that of liquid oxygen/kerosine. Because of the very low density of liquid hydrogen (0·07 gm per cc), those combinations in which it is used have a much lower mean density, thus offsetting their high specific impulse. The performance advantage of any particular combination of specific impulse and mean density will depend

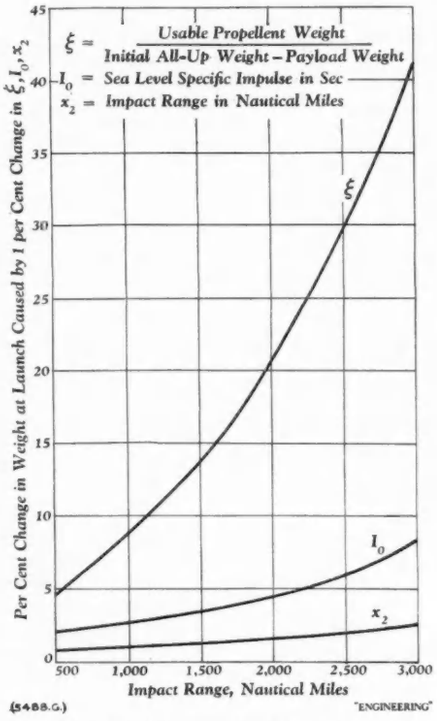

ξ = Usable Propellent Weight / Initial All-Up Weight − Payload Weight
I_0 = Sea Level Specific Impulse in Sec
x_2 = Impact Range in Nautical Miles
Per Cent Change in Weight at Launch Caused by 1 per Cent Change in ξ, I_0, x_2
ξ
I_0
x_2
Impact Range, Nautical Miles
(5488.G.)
"ENGINEERING"

Fig. 7 Effect of changes in design parameters on missile weight.

on the application considered, but over quite a wide range of long-range rocket requirements, roughly the same performance is given by the following combinations:—

Specific impulse, sec.	Mean density, gm per cc
350	0·4
300	1·0
270	1·6

Recent developments in the field of solid propellents for rockets have led to specific impulse figures approaching those of available liquid propellents. So far, however, the associated structure weights are appreciably higher, and, as a general rule, any long-range task will require an additional stage if solid propellent is used instead of liquid. Against this must be set the great engineering simplicity of solid-fuel rocket motors, and, in particular, the elimination of all the intricate "plumbing" required by large liquid-fuel propulsion systems. This should greatly ease the problem of achieving high motor reliability in operation. Although high-performance solid propellents are not by any means without their problems, recent American publicity about solid-propellent long-range rockets shows a current trend in their favour.

POTENTIALITIES OF NUCLEAR ROCKET PROPULSION

Although the application of nuclear propulsion to rockets is a task for the future, it is perhaps worthwhile to indicate the order of performance advantage it might offer. As at present envisaged the nuclear reactor would be used merely as a source of heat, and a working fluid of low molecular weight would be fed to the reactor, heated there in gaseous form to as high a temperature as the materials of the reactor would allow, and then exhausted through a conventional rocket nozzle. The specific impulse attainable with such a device varies roughly as $\sqrt{T/M}$, where T is the gas temperature in the reactor, and M the mean molecular weight of the exit gases. The requirements are thus for high temperature and low molecular weight. The latter points at once to hydrogen, which, with its uniquely low molecular weight gives a much higher specific impulse than any other working fluid. The temperature limit will be set by reactor materials, and might approach 4,000° K if one of the refractory carbides such as tantalum carbide or hafnium carbide, with melting points approaching this figure, could be used.

A nuclear rocket using hydrogen would give a specific impulse of about 800 seconds for T = 3,000° K and 1,000 seconds for T = 4,000° K; Fig. 10 indicates the great reduction in the required mass ratio when the specific impulse is so large. The nuclear rocket is not yet available, and is likely to be much heavier than conventional rocket propulsion systems.* Its use is likely to be in space travel applications which are beyond the capabilities of conventional rockets.

TERMINAL ACCURACY

The accuracy with which a long-range ballistic rocket will reach its prescribed destination, or with which an earth satellite achieves a planned orbit, depends on its position and velocity at the termination of its propulsion. The required conditions at motor cut-off are readily related to the terminal accuracy for a long-range rocket, and the requirements for accuracy in velocity

* *Editor's Note:* See "Nuclear Propulsion," by J. Edwards. British Association paper, 1958.

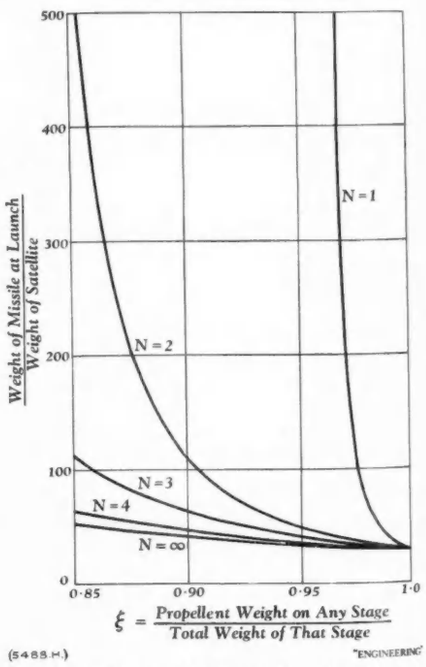

Weight of Missile at Launch / Weight of Satellite
N = 1
N = 2
N = 3
N = 4
N = ∞
ξ = Propellent Weight on Any Stage / Total Weight of That Stage
(5488.H.)
"ENGINEERING"

Fig. 8 Variation of weight at launch with structural efficiency factor ξ and the number of stages of propulsion, N, for a satellite missile.

measurement will invariably make the more stringent demands on the guidance system. Fig. 11 shows the relation between the velocity errors in three orthogonal directions at motor cut-off and the resultant errors at the point of arrival for ballistic rockets having a range up to 5,000 miles. By far the most stringent requirement is for velocity accuracy along the trajectory. This is $1\frac{1}{4}$ ft per sec per mile error for a 5,000 mile rocket, corresponding to an accuracy in velocity measurement of 5 parts in 10^5 per mile error. The accuracy requirement in azimuth is rather less, and there is a great relaxation normal to the trajectory and in the plane of the trajectory because the rocket is always assumed to be operating at maximum range and flying along a trajectory with the appropriate elevation at motor cut-off. The guidance requirements for earth satellites are less straight-forward to define because the accuracy characteristics required of the satellite orbit are likely to vary greatly with the purpose for which the satellite is intended.

In the early attempts to produce an earth satellite, the precise orbit to be achieved has obviously been of minor significance. Any orbit

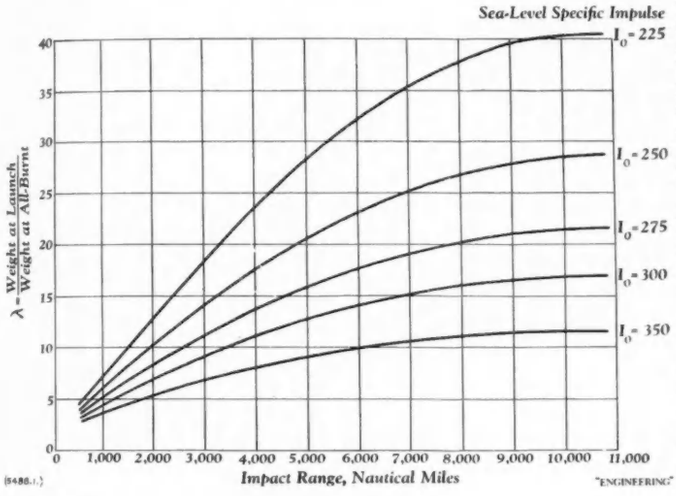


Fig. 9 Variation of λ with impact range, for ranges up to 10,800 nautical miles, and for a series of values of I_0.

within rather wide limits is a success. For example, the declared object of Project Vanguard* was to achieve an orbit with inclination to the earth's equator $35° \pm 5°$ (corresponding roughly to $\pm$ 2,000 ft per sec normal to the plane of the trajectory), with perigee altitude greater than 200 nautical miles and apogee altitude less than 1,400 nautical miles, the latter requirement being relaxed subsequently. With these wide limits there is considerable scope for easing the guidance requirements in the plane of the trajectory if additional velocity at cut-off can be provided. The increasing tolerance on the elevation of the satellite trajectory at cut-off as the velocity available increases is shown in Fig. 12 which is taken from Rosen's paper. Cut-off velocity is shown as a percentage of circular orbital velocity at 300 nautical miles altitude, and the nominal altitude of entry into the orbit is 300 nautical miles. Thus, in Fig. 12, the point $\gamma = 0$, $V = 100$, represents a circular orbit, and any point within the shaded area meets the requirement of perigee altitude greater than 200 miles and apogee altitude less than 1,400.

Fig. 13 gives an indication of the accuracy which must be obtained in the magnitude of the velocity at cut-off and in direction relative to the local horizontal if near-circular orbits are required. It shows, for a nominal circular orbit at 300 nautical miles altitude the effect of errors

* "The Satellite Launching Vehicle," by Milton W. Rosen. High Altitude and Satellite Rocket Symposium, Cranfield, July, 1957. See ENGINEERING for 26 July, '57, p. 98; and 18 Oct., '57, p. 484.

at cut-off on the height of apogee and perigee. Thus a demand for an orbit in which apogee and perigee do not differ by more than 25 miles allows a tolerance in the magnitude of the cut-off velocity of $\pm$ 40 ft per sec if guidance in elevation is perfect and, if cut-off is achieved at exactly the velocity for a circular orbit at 300 miles, a tolerance in the direction of the velocity of $\pm 0{\cdot}2°$.

The process of meeting these accuracy requirements may usefully be divided into two phases, corresponding to "guidance" and "control." The first consists of determining the position and velocity of the missile during its powered flight, and of computing the corrections to the flight path which must be made to achieve the required terminal conditions; the second is concerned with the application of these corrections to the flight path. Before discussing the means by which these objects may be achieved, something must be said of the general principles on which the guidance of ballistic rockets or satellites can be based.

There are two extreme possibilities. The first would attempt to constrain the missile to follow, as accurately as possible throughout its powered flight, a trajectory predetermined in shape and timing. Such a system puts the maximum of constraint on the missile, particularly so far as the thrust control of its motor is concerned. The other extreme would put the minimum of constraint on the trajectory, allowing the missile to depart from its nominal trajectory because of changes from their nominal values of missile drag, thrust, etc., or because of the effects of steady winds or gusts in the atmosphere. In the second case the velocity vector required to carry the missile to its target, or the satellite into its orbit, is computed continuously and the missile controlled so as to reduce the differences between the computed and the actual velocity vectors to zero.

There is a wide range of possibilities between these extremes and the choice for a particular application requires a detailed assessment of the whole system—the missile, its motors and control system, and the method used for guidance and the interaction of each with the others.

GUIDANCE

Methods of guidance for long-range rockets and satellites may be divided into two types:—(1) Measurement of range elevation and azimuth and their time derivatives from one or more radar stations on the ground. From this information missile position and velocity may be computed, and then appropriate demands to the missile control system generated in a ground computer and sent by radio link to the missile.

(2) The continuous measurement of missile acceleration and, by integration, of its velocity and position by means of an inertia navigator in the missile. Measured position and velocity are then compared with desired values stored in a computer in the missile, and the appropriate control demands generated.

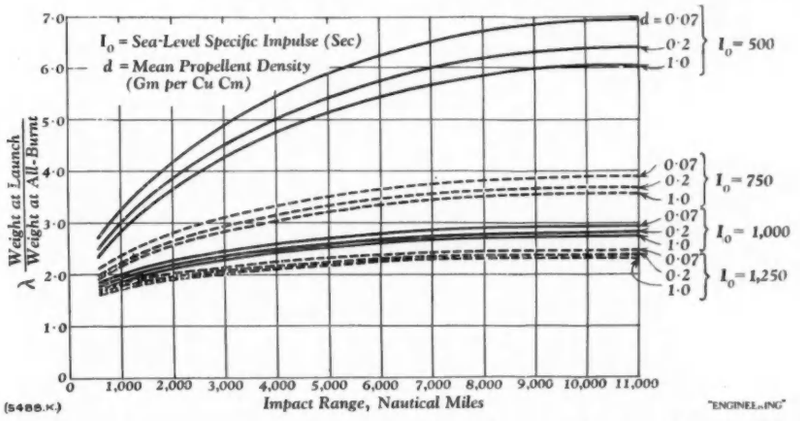
There are some potential advantages, discussed later, to be gained from a guidance system employing a combination of these two methods. The more flexible the guidance philosophy, and the smaller the constraint on the missile, the more complex will be the computations to derive control signals from the measured missile kinematics. Because the guidance computer in the inertia method is missile borne, and hence must be as small and light as possible, this method tends to be associated with a less flexible guidance philosophy, and with greater constraints in the missile. There is little restriction on the size, weight or complexity of the ground computer for a radar guidance system.

RADAR GUIDANCE

Just as in any other high accuracy radar measurement or guidance system, the design of a guidance system for a long-range rocket or satellite depends on the sources, magnitude and frequency distribution of the noise in the system. These include noise in the missile acceleration (and hence in position and velocity) due to variations in the magnitude of motor thrust, and noise in the radar measuring system due to inhomogeneities in the atmosphere and ionosphere, and to ionisation in the rocket flame, causing variations either in the direction or velocity of the radar beams, or both. In addition, there will be noise introduced by the radar receiver and possibly by the servo system driving the ground aerials.

Some of these effects can be mitigated by using long smoothing times in the measurements, but the consequent time lags and staleness of the information introduce additional difficulties, particularly so far as accurate cut-off of velocity is concerned. The ground computer is likely to take an appreciable fraction of a second to predict from the raw radar observations the appropriate cut-off time. This prediction must make allowance both for the staleness of the information and for the prediction dead time, and if the prediction time is too long the effects of motor noise may introduce intolerable errors in the cut-off velocity achieved. This situation can again be eased by cutting off the main propulsion system somewhat before the desired speed is reached, and by using a low thrust or "vernier" motor, in which thrust irregularities will cause much smaller errors in the achieved cut-off velocity, to bring the missile accurately to its final cut-off conditions.

Fig. 10 Variation of initial all-burnt weight ratio λ with impact range for one-stage missiles having specific impulses between 500 and 1,250 secs.



The demands on the radar measurement of angular rate are most stringent (accuracies of a small fraction of a mil per sec), and are likely in some applications to be beyond the capacity of the conventional polar-tracking radar, and to demand the use of phase-comparison systems.

INERTIA GUIDANCE

The heart of an inertia-guidance system for a long-range rocket or a satellite is the space-stabilised inertia platform, carrying three orthogonally mounted accelerometers. The platform is maintained at a constant attitude in space, irrespective of the motion of the missile in which it is mounted, by servo motors using error signals derived either from a pair of gyros having two degrees of freedom or from three single-axis instruments mounted on it. In addition there are a pair of integrators associated with each accelerometer producing missile velocity and displacement along the three orthogonal axes. These outputs are fed to the guidance computer in the missile which generates the appropriate control signals. The main problem in the development of inertia guidance systems lies in the design of components, particularly gyroscopes and accelerometers, of sufficient accuracy and stability of performance.

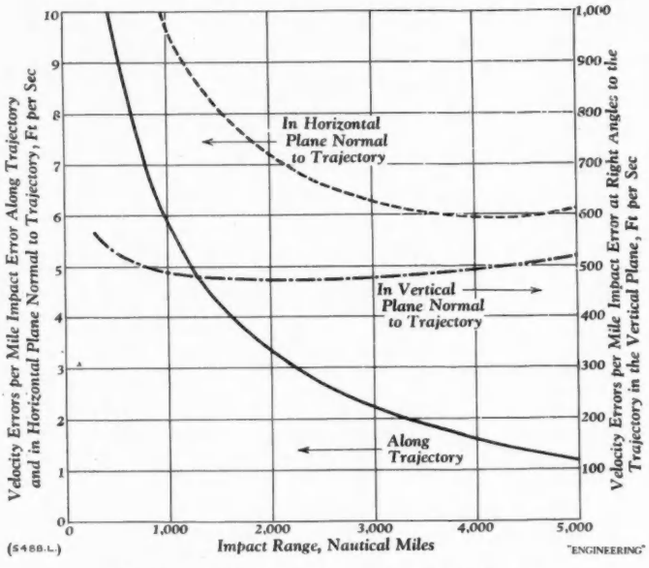


Fig. 11 *Velocity errors per mile error at impact.*

The criterion of gyroscope performance is the magnitude of its "wander" rate, or rate of change of direction of its nominally invariant spin axis, and the objective is to reduce this quantity to a small fraction of a degree per hour. This aim has become realistic only since the development of the "flotation" gyro, in which the inner gyro element is floated in a heavy liquid such as Fluorlube or mercury, thus transferring its weight from the gimbal bearings to the liquid, and greatly reducing the frictional forces at the bearings. Even with the advent of the flotation gyroscope, the achievement of wander rates of less than a degree per hour calls for extreme skill in mechanical design and the utmost precision and cleanliness in manufacture.

The measurement in the laboratory of the performance of these instruments is a difficult and complex process,* and so also is the extrapolation from laboratory performance to the behaviour which is to be expected in the much more disturbing environmental conditions in a long-range rocket or satellite. Adequate laboratory tests can be made of the effects of vibration, temperature changes, etc., on wander rate, but the effects of sustained and steadily increasing acceleration (from an apparent acceleration of perhaps $\frac{1}{2}$ *g* up to 10 to 20 *g* over a period of 2 to 4 minutes or longer) which the gyroscopes will experience during the missile's powered flight, can only be determined by rocket flight or, possibly, by the use of a rocket runway.

The three main types of accelerometer suitable for the inertia guidance of rockets or satellites are all based on the measurement of the force exerted on a constant mass. They do this by:—
(*a*) balancing against the force exerted by a magnet on an electric current (force feed-back system);
(*b*) by balancing against the tension in a wire, the frequency of vibration of the wire being used as a measure of the tension; or
(*c*) by applying the force as a torque to precess an out-of-balance gyro, the rate of precession being a measure of the acceleration.

The requirements are very stringent, since the accelerometer has not only to measure very small accelerations of order 10^{-4} or $10^{-5}g$ which means that the mass must be suspended in such a way that the forces exerted by the suspension are small compared with the smallest force to be measured, but also to operate accurately over a very wide range, up to 10 to 20 *g*. In addition, the suspension must be capable of taking continuous loads at right-angles to the direction of measurement of 10^5 to 10^6 times the minimum force.

The out-of-balance gyro accelerometer can be arranged to perform the first stage of integration itself and give an output proportional to missile velocity, and the frequency output of the vibrating-wire instrument can readily be converted by cycle counting to give a velocity output. The force feed-back instrument must be followed by two stages of integration, the first of which needs to be highly accurate. Integration is generally performed either by a Miller integrator or tacho-generator, and the design problems of obtaining the necessary accuracy in the first stage are difficult.

COMBINED SYSTEMS

The error characteristics of the two types of measuring systems, radar and inertia, are partly complementary. The radar system has excellent long-term stability but suffers from noise at higher frequencies, whereas the inertia system has little high frequency noise but suffers from long-term drifts. When the highest accuracy is required these systems can with advantage be combined, and less stringent requirements can be met by a combined system with useful relaxations in the accuracy required of each component.

A small improvement in accuracy can be obtained if all that is known about the errors of the two measuring systems are their mean square values. Thus if estimates of missile velocity, for example, are available from a radar system with mean square error σ_R^2, and from an inertia system with mean square error σ_I^2, then by forming the appropriate weighted average (the weighting factors being determined from the mean square errors of the two systems), the mean square error in velocity from the combined system, σ^2, can be reduced to

$$\sigma^2 = \frac{\sigma_R^2 \sigma_I^2}{(\sigma_R^2 + \sigma_I^2)} \quad . \quad . \quad . \quad (8)$$

Further improvement can be obtained if the frequency distributions of the random errors in the two measuring systems are known. The weighting factors are then replaced by time-dependent weighting functions, determined from the spectral densities of the random errors in the two systems in such a way as to reject those frequencies in either system at which noise is troublesome, and to minimise the resultant mean square error.

SATELLITE GUIDANCE

Although the guidance techniques discussed above apply both to long range rockets and to satellites, there are some special circumstances which affect their use for the latter. These are related to the nature of the satellite climb path into orbit, and to the need in a multi-stage vehicle launching a small satellite, such as Vanguard, to keep the payload in the final stage as light as possible. In these circumstances, provided adequate terminal accuracy can be achieved, there is everything to be said for carrying the necessarily rather heavy guidance equipment in an early stage; with subsequent stages controlled, possibly to a pre-set programme, but unguided.

The climb programme of a satellite will generally consist of one or more stages of propulsion, followed by a period of ballistic flight or coasting up to orbital altitude, and finally a short period of thrust, aligned to be horizontal for a circular orbit, that brings the speed up to the required orbital value. It can be shown that the best performance is achieved by making the velocity increment on entry into orbit as small as possible. The total velocity requirement on the two phases of propulsion will be minimised if the loss in velocity during the coasting phase is made as small as possible. If the velocities at the beginning and end of coasting are V_1 and V_2 and the distances from the earth's centre are r_1 and r_2, the energy equation gives

$$\tfrac{1}{2}(V_1^2 - V_2^2) = g R^2 \left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad (9)$$

where R is the radius of the earth. The right-hand side of the equation may be taken as constant so that the loss in velocity, $V_1 - V_2$, decreases as V_1 and V_2 increase; V_1 should therefore be made as large as possible, and the optimum coasting path *in vacuo* would be an ellipse going half-way round the world. For a circular orbit at 500 miles altitude, for example, the missile would complete its first and major phase of propulsion at around 100 miles altitude, and begin coasting horizontally at a velocity some 700 ft per sec in excess of the circular orbital

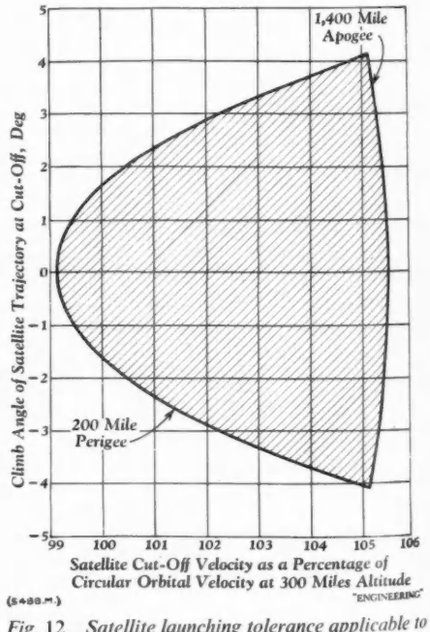


Fig. 12 *Satellite launching tolerance applicable to a launching altitude of* 300 *miles for a* 200 *mile perigee and a* 1,400 *mile apogee.*

* "Some Design Problems on Inertia Navigation," by W. Cawood. Communication aux Journées Internationales de Sciences Aeronautiques, Paris, May, 1957.

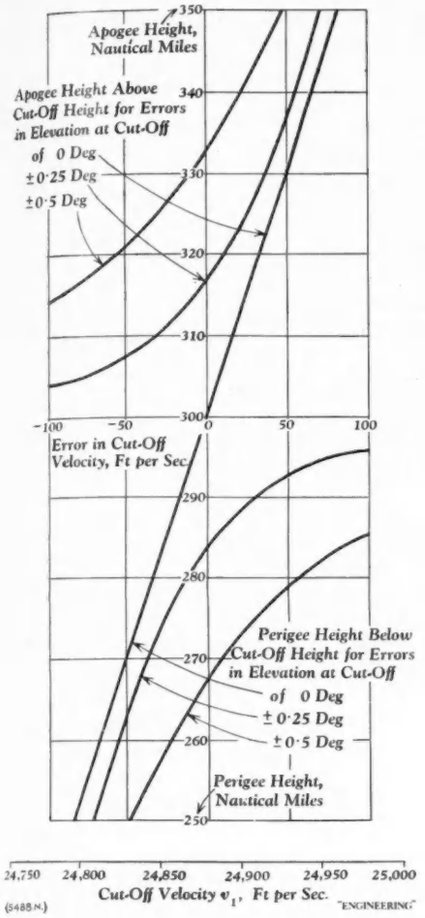

Apogee Height, Nautical Miles
Apogee Height Above Cut-Off Height for Errors in Elevation at Cut-Off of 0 Deg
±0·25 Deg
±0·5 Deg
Error in Cut-Off Velocity, Ft per Sec
Perigee Height Below Cut-Off Height for Errors in Elevation at Cut-Off of 0 Deg
±0·25 Deg
±0·5 Deg
Perigee Height, Nautical Miles
Cut-Off Velocity v_1, Ft per Sec.
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Fig. 13 (above) The effect of errors at propulsion cut-off on a near-circular satellite orbit.

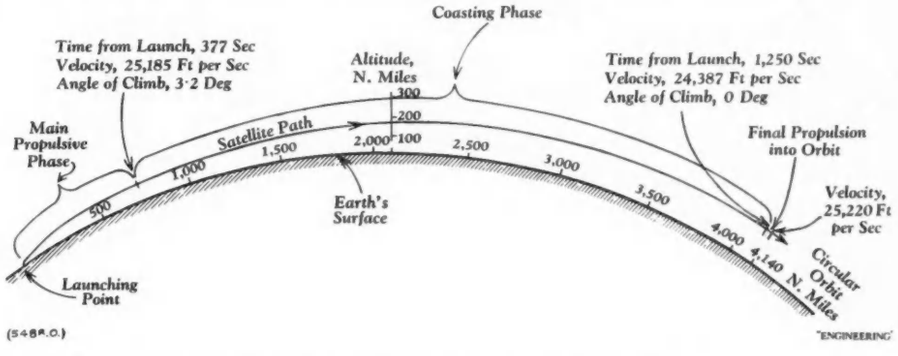

Fig. 14 (right) Typical satellite climb path.

velocity at that altitude. It would finish coasting, again going horizontally at the desired orbital altitude, at a point diametrically opposite to its starting point, having lost only some 2,700 ft per sec and needing a velocity increment to enter the circular orbit of about 700 ft per sec.

These conclusions apply for motion *in vacuo*, and the long coasting period does increase very slightly the loss in velocity due to drag, so that the optimum path in the presence of the atmosphere has a rather shorter period of coasting. Fig. 14 shows a typical climb path for a circular orbit at 200 miles altitude.

For the highest accuracy, guidance must be exercised during the final period of thrust when, with the climb paths derived above, the satellite has been in flight for some 20 minutes and is several thousand miles from its launching point. The long duration of guided flight stresses the demand for low wander rate of the stabilised platform of an inertia system; and the great separation between the missile at launch and during the final guided phase means that an accurate radar tracking system must be deployed forward of the launching point. There is also a difficult problem with a pure radar-guidance system of achieving the correct orientation of the satellite prior to the final thrust into orbit.

The first American satellites, Vanguard and Explorer, have both been designed around existing propulsive stages, and neither has used the optimum staging arrangement, nor the optimum climb path into orbit. In both cases the satellites have reached orbital height at a comparatively low speed, with a high velocity loss during coasting, and consequently a high final velocity increment to reach orbital speed (about 50 per cent of orbital velocity for Vanguard).

In these early firings, guidance accuracy has not been of paramount importance and, because of the crushing effect of deadweight in the final stage, active guidance has not been employed right up to the entry into orbit, thus allowing the guidance equipment to be carried in an earlier stage. In Vanguard, for example, only the first and second of the three stages are guided (by an inertia system). Separation of the second and third stages does not occur immediately after second stage burn-out, but both stages (the second stage carrying the guidance equipment and controls) coast up from about 135 miles to orbital altitude. During the coasting period the vehicle is correctly oriented for the projection of the third stage, the time of firing of the third stage is determined from conditions at second stage burn-out and the necessary rotation is imparted to the solid propellent third stage to give it adequate stability during its powered flight. A similar procedure is adopted in Explorer, with both the final solid-propellent stages being spin stabilised.

CONTROL SYSTEMS

The primary function of the control system of a long-range rocket or satellite-launching vehicle is to cause the missile to follow in a stable fashion the demands of the guidance system, or sometimes of a pre-set guidance programme. In addition cut-off of the motor must be executed on receipt of a signal from the guidance computer.

Because of the absence of any appreciable atmosphere over a large portion of the powered trajectory, conventional aerodynamical control surfaces are of no use, and reliance for steering must be placed instead on jet reaction. The couples necessary to change the altitude of the missile are usually produced by deflecting the efflux jets from the main motors, the thrust line of which, in their undeflected state, passes through the centre of gravity of the missile. In a liquid-propellent missile, with flexible connections between propellent tanks and the thrust chamber, jet deflection is readily achieved by mounting the whole thrust chamber on gimbals, and deflecting it by means of servo-controlled hydraulic jacks. The deflection of the nozzle of a solid-fuel rocket raises considerable engineering problems of materials and sealing because of the high gas pressures and temperatures involved; but there are a number of other possibilities for jet control of such rockets, for example, by introducing movable vanes into the jet, as in the V-2, or by means of some form of movable deflector system protruding into the jet near the nozzle exit plane.

A single-gimballed motor can only exert control in yaw and pitch, but not in roll, so that with a single-motor installation additional means of roll control must be provided. This may be done either by auxiliary roll jets, or, for a liquid-propellent system, by deflecting the efflux from the turbo-pumps used to drive the propellents into the combustion chamber.

Flexibility of the missile structure can give rise to one of the key problems in control system design. The control system will usually operate so as to eliminate any difference between missile altitude, as demanded by the guidance system, and missile attitude, as measured by the sensing instruments (such as gyroscopes or accelerometers mounted in the missile). These instruments will detect the structural vibrations of the missile and, should the phase and gain of the control loop happen to be adverse at a particular structural vibration frequency, instability and a divergent oscillation may be caused. This difficulty is dealt with either by suitable location of the sensing instruments, by artificial attenuation of the control system response at the relevant frequencies or by the introduction of artificial damping, or generally by a combination of these methods.

An additional possibility of control-system instability to be found in large liquid-propellent systems arises from the " sloshing " of the propellents in their tanks. This may best be attacked at source by means of some form of " anti-slosh " baffle in the tanks.

The problem of thrust cut-off in a liquid-propellent system is a comparatively straightforward one; the main difficulty, when the highest accuracy is required, lies in ensuring that the total impulse during the thrust die-away period is sufficiently closely repeatable from run to run. Thrust cut-off of solid fuel motors is less straight-forward, but can be achieved by the opening of vents in the motor case, thus reducing internal pressure and causing combustion to cease. Once again the problem is to obtain repeatable total impulse along the motor axes during thrust die-away, and also the absence of appreciable lateral impulse.

Acknowledgment.—I am indebted to a number of my colleagues at the Royal Aircraft Establishment for assistance during the preparation of this paper; in particular, to Mr. D. G. King-Hele, who was responsible for most of the information on the performance of long-range rockets and satellites. The paper is Crown Copyright reserved and is reproduced by permission of the Controller, H.M. Stationery Office.

SOLID CIRCUITS: USE IN CONTROL SYSTEMS

Solid state circuits which do not require internal wiring or conventional components are being studied in the David Sarnoff Research Centre, Radio Corporation of America, Princeton, N.J. An integrated shift register has been fabricated from a single bar of germanium 0·5 in long, 20 mils wide, and 4 mils thick. Ten transistor-like elements are contained in this strip and they function as ten separate two-way switches connected in series. Between the separate transistors, the germanium bar performs the functions of the interconnecting circuits that would be needed in a conventional shift register. As a result, the new device has integrated into it not only 10 transistors but also the operational functions of 20 resistors and 10 capacitors.

The company expect that the integrated-device approach can be extended to other sub-assemblies, made up of identical stages, for use in computer and control systems. In addition it is possible that integrated units can be used in other areas where individually designed stages are now employed, as in radio receivers or audio amplifiers.

Continuing

Research and Development

TAKING THEIR MEASURE

The United States National Science Foundation, Washington D.C., recently held a one day conference on " Research and Development and its Impact on the Economy." About 400 representatives attended. Dr. A. T. Waterman, director of the Foundation, voiced the theme of the conference when he pointed out that three underlying ideas had recurred throughout. The first of these was the interdependence of Government, industry, and universities and other non-profit institutions in supporting and performing research and development. The second was the interdependence of the various phases of the research process, namely the close relationship of basic to applied research and the necessity for a better allocation and balancing of research resources. The third idea was the inter-relationship of research in the natural sciences and the state of economic knowledge.

The state of research on research received comment from more than one speaker. Mr. R. E. Burgess, speaking on " The Impact of Research and Development on the Chemical Industry " claimed: " For all practical purposes, the individual firm has no yardstick by which to judge the excellence of its distribution of research funds between basic and applied research . . . The distribution is not predetermined but rather the natural result of projects undertaken . . . As with the problems of determining the overall amount of research appropriation, the question of how systematically to allocate funds among research types lies in the dark areas of our understanding." A somewhat more optimistic view was taken by Dr. G. C. Suits. Speaking on " The place of Basic Research in Private Industry " he suggested: " These problems of planning basic research are difficult, but they are not insoluble. If we could put to this task a small fraction of the courage and determination we use to solve scientific riddles, the results would be astounding. I believe that the steps which we must take are becoming clear, and that some real progress is in the making."

The National Science Foundation is engaged in two studies related to research on the research process. The first of these is being conducted by the Case Institute of Technology, in co-operation with personnel of the Office of Special Studies. It will concentrate initially on developing a methodology and " model " for determining the relation of research and development to the growth of a company. The second phase of the study will extend the methodology to a number of additional firms in the same industry and permit a generalised approach for a single industry. The next phase will extend the model to study the effects of research and development on inter-industry relationships. This will include the competitive effect of research in one industry upon another as well as its effect on complementary industries. Eventually, it is hoped, an attempt will be made to extend this analysis to measure the impact of research and development upon the total economy.

The Carnegie Institute of Technology is conducting a study on the effect of decision-making as it relates to innovations resulting from research and development. The study will examine the ways in which innovations communicated within the firm eventually become an accepted part of a new product or process within an industry or industries.

Engineering at Home

ELECTRIC SHOCK

Electric power in a house enables the use of many labour-saving devices and brings comfort by way of light and warmth. But at the same time, like all other sources of power, it requires to be treated with circumspection; the installation and maintenance of electrical equipment should be undertaken by people who understand what they are doing.

The fatal accidents caused by electrical equipment on premises of a domestic or similar character, notified to the Home Office as having occurred in Great Britain during the year 1957, numbered 66; a very small figure in comparison with the number of people using electric power. From a summary of a number of the accidents, it is apparent that, as Mr. S. J. Emerson, H.M. electrical adviser to the Home Office, puts it, " accidents are due not to faulty appliances but to misuse of equipment, human errors, and mental aberration on the part of the user."

The danger of taking portable electric lamps into bathrooms is made evident by the following fatal accidents. A small boy was killed when he touched a defective lead to a lamp while he was sitting in a bath full of water. A girl was electrocuted when a metal reading lamp fell from the side of the bath into the water. A man was killed when a defective reading lamp fell from the bathroom window sill into his bath-water. And lamps are not the only source of danger. A woman was electrocuted when she touched the accidentally electrically charged non-earthed metalwork of an electric fire while taking a bath. One young man was electrocuted when an electric iron fell from the ironing board at the foot of the bath into his bath water.

Many accidents resulted from faulty adaptation of electrical devices. A man received a fatal shock when using a portable electric drill he had brought home from work to do a job on his car. He had removed a 3-pin plug from the lead attached to the drill and replaced it with a two-pole bayonet cap adaptor, so that it could be inserted into a lighting socket. The bare end of the earth wire had been left free inside the adaptor and it came into contact with the live terminal. As a result, the non-earthed metal casing of the drill became live at mains voltage.

Accidents caused by faulty wiring were frequent. A baby crawled from his cot and was electrocuted when he came into contact with the element of an old unguarded electric fire, which was switched off at the time. The single-pole switch controlling the fire was connected in the neutral conductor so that the element was always electrically alive. A housewife was killed by electric shock when she touched the non-earthed metalwork of a washing machine located in an outhouse. The supply to the machine was switched off at the time of the accident, but a defective joint in the supply cable resulted in the non-earthed metalwork being charged at mains voltage. The joint was located out of doors beneath a rainwater down spout and had been made by an amateur electrician in such a manner that the earth wire, which was disconnected from the main earth connection at the origin of supply, was making contact with the live conductor due to defective insulation in the joint.

CONTROLLING PLANT GROWTH ELECTRICALLY

Electrical techniques, including seed germination on soil-warmed benches, supplementary lighting by high-pressure mercury-vapour lamps, and thermostatically-controlled space heating, are displayed on the electricity stand at the Southport Flower Show (27-29 August). One of the main items is giant tomato plants: twelve plants between 18 ft and 20 ft high and yielding an average of 22½ lb of fruit per plant were exhibited last year to bring home to growers the advantages of the application of electrical methods to horticulture. The stand has been organised jointly by the Merseyside and North Wales Electricity Board, the North Western Electricity Board, and the Electrical Development Association. The Association has its headquarters at 2 Savoy Hill, Strand, London, W.C.2.

An enclosed propagating case shows growers how to provide different climates in the same greenhouse. By using soil warming and controlled space heating, soil and air temperatures of over 60° F are maintained in the cases without incurring excessive fuel bills. Another display features the controlling of chrysanthemum flowering. By applying supplementary lighting from tungsten-filament lamps between the hours of midnight and 2 a.m. in the autumn, bud initiation in mid-season and the formation of late varieties are delayed. Similarly, by the discriminating use of tungsten-filament lamps and shading, chrysanthemum varieties may be flowered at any season of the year.

LISTENING FOR LEAKS

Although the extent of leakage from water mains in Britain is not known, in other countries it appears to be between 20 and 30 per cent. Discovery and measurement of the leakage is carried out by metering the flow at night in sections of the supply service. However, the exact location of the leak in pipes 3 ft or more underground is often a matter of great difficulty. It is accomplished by listening for the hiss of escaping water, which requires a skilled operator working in the quietness of the night.

The Water Research Association, Redhill, Surrey, have been investigating electronic leak detectors. They have found that the noise of a leak is essentially of the same character as the background noise of an electronic amplifier and that no electro-acoustic detector can be designed to respond specifically to a leak noise. The external background noise—traffic, wind in the trees, rain—is also not fully distinguishable from the noise of escaping water. However, the association have designed an instrument that when set to respond to a noise above a certain level will light a lamp if placed on a road surface above a leak. Other methods of detection are under consideration.

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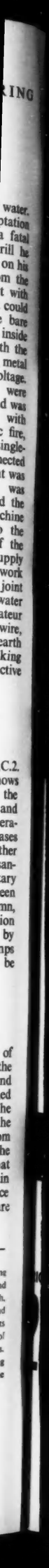
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